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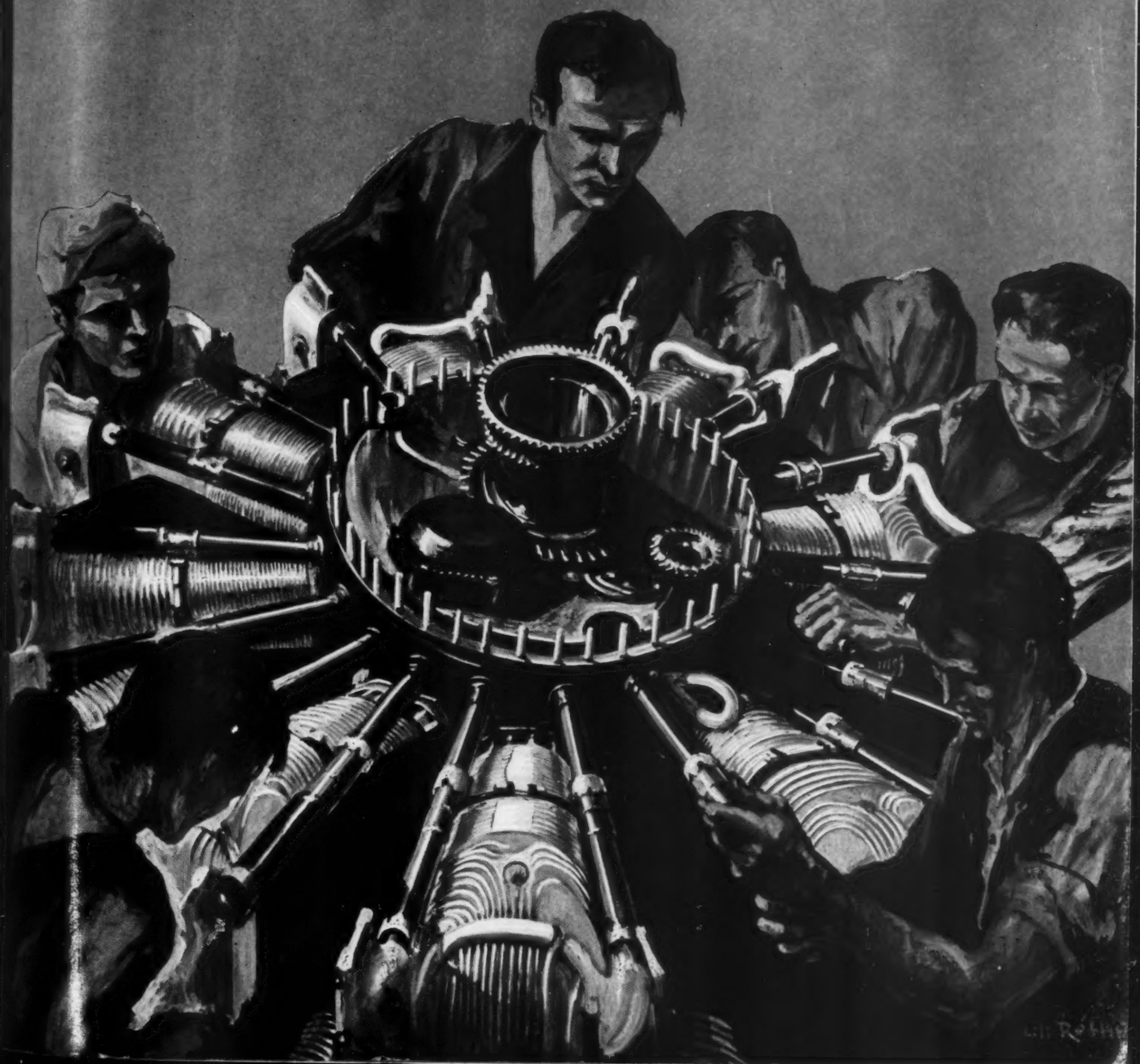
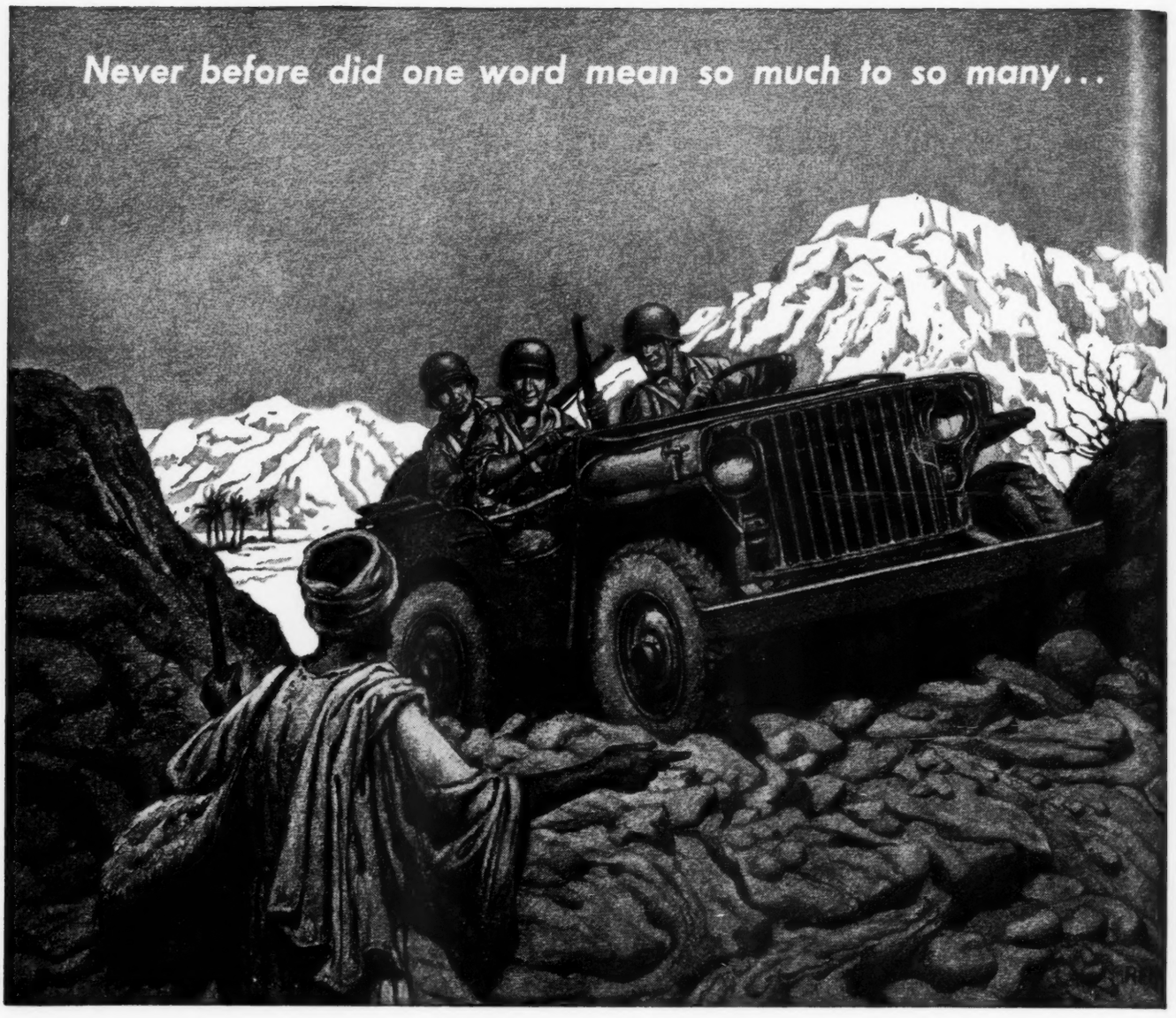
PRODUCT ENGINEERING

FEBRUARY 1943





You can serve by CONSERVING

Name a continent . . . and you've named an American battlefront. From Tunisia to Timor, from India to Iceland, Americans and their Allies face a need for more arms and equipment . . . more tanks and trucks, more planes and ships and guns.

And those modern weapons need alloy steels in vital parts. Nickel steels, for example, that provide extra toughness, strength and added resistance to shock and impact. No need to tell you how essential these qualities are to the equipment of our armed forces.

That's why it's so important to *conserve* critical alloys. Every possible pound must be saved for our fighting men.

The best way to help is by making sure all metal scrap in your plant is properly segregated. Collect ferrous and non-ferrous scrap, in separate containers, at the machines where generated.

High-speed tool steels and alloyed constructional steels should also be collected and salvaged separately. When in doubt . . . segregate!

If metal problems are bothering you—if you would like suggestions for extending your own metal conservation program—call on our technical staff for "CONSERVICE,"—a new name for counsel and data that will help you conserve.

★ ★ **Nickel** ★ ★

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

PRODUCT ENGINEERING

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IN THIS ISSUE

P. E. Adopts Smaller Trim Size

Readers will observe that the "trim size" of the current issue of the magazine is slightly smaller than that of previous numbers. The reduction in size has been made to enable the publishers to meet an order of the War Production Board limiting the amount of paper that may be used in 1943. Subscribers will note, however, that no change has been made in size of type or in the amount of editorial content per page, but that a substantial saving in paper has been effected merely by trimming the margins.

The publishers have adopted the new size as a war measure and as a contribution to the conservation of manpower and transportation facilities in the production and distribution of paper. Service to the reader has not been sacrificed and will be maintained as far as humanly possible in the face of the problems confronting all of us in our united efforts to win the war.

Cover Picture

Generating 1,850 to 2,000 hp., Ford-built Pratt & Whitney engines are made to watch-like precision in a modern mass-production plant. The Ford-developed method of centrifugally casting cylinders is employed in making these engines. For every motor built this way, four hours' time is saved and a third less critical material used.

Tests That Check Bomb Fuzes

The ultimate in testing any pudding is in the eating thereof, and by the same token the ultimate test that any product is subjected to is its use. It was found by experience that the conventional tests on bomb fuzes did not indicate with any degree of accuracy how fuze would work when put to use. The critical element in such fuzes is the length of time that elapses between the time the bomb leaves the plane and the fuze is "armed." The article by A. L. Atherton beginning on page 95, explains how "wind tunnel" tests were developed by means of which the fuzes were given a

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"sure" test. Facts revealed by the tests lead to further improvements in the fuzes.

What Material Is the Best?

There is no answer to this question because often it is possible to use any one of several vastly different materials and get equally good results. It is not so much a question of what material is being used as it is a question of how well the designer is using it. In a highly interesting analysis beginning on page 67, Fletcher Platt, stress analyst of Fleetwings, Inc. explains the design factors that influence the weight and efficiency of the finished structure.

Rubber-Like Synthetic Resists Corrosion

Corrosion-resistance of chemical stoneware with the desirable characteristics of rubber are two important features of a new synthetic called Tygon. It is available in forms ranging from liquid to bone-hard and consists of modified halide polymers, new condensation resins and diene derivations. U. S. Stoneware Company developed the material.

War needs limit the use of Tygon to only essential purposes; but capacity expanded to meet war demands will be available for the needs of peace. Meanwhile, development work on Tygon is continuing. For all available information, including properties and chemical resistivity, see page 88.

American Standards Color Specifications

The only scientific method for specifying or describing color has been extremely technical in character. In order to popularize this system and enable it to be interpreted in familiar terms the American Standards Association recently adopted a standard for the specification and description of color. This standard should go a long way to promote the proper use and description of color. See page 91.

Finishing Aluminum Parts

Many engineers other than those engaged in the air craft industry will find practical use for the data presented in the article, page 99, "Finishing Aluminum Parts for Military Aircraft."

Induction Heating

Close control and fast action in production scale brazing and soldering operations with unskilled workers has been accomplished by adapting high-frequency induction heating to industrial equipment. J. P. Jordan, General Electric Company, discusses the basic principles of the process on page 102 and tells how to design joints to be made by the induction heating method.

Stress Concentration Factors

Determination of stress concentration factors has been the goal of many researchers in the study of the strength of various types of unavoidable weak spots in design. Most of such projects have resulted in single factors applicable to only one type of stress concentration. George H. Neugebauer, whose article last month dealt with the effect of material and loading in calculating design stress, has classified a large portion of the existing information on stress concentration factors and has arranged it systematically for most convenient use. His article and tabulation start on page 82.

Adhesive Applicators

Proper control in the application of viscous liquid adhesives to maintain the pace set by automatic machines for packaging or for various fabricating operations has occupied the attention of many engineering departments. A number of mechanisms that have been devised for this purpose are illustrated on pages 106 and 107. Others will follow next month.

Dimensional Tolerances

Except for careless handling and abuse, the two major factors which cause machined parts to be scrapped are incorrect dimensions and finish. Incorrect dimensions are frequently the result of errors made in the tooling dimensions specified to control lengths, widths and thicknesses especially when the dimensional relationship of the surfaces of the finished part is the result of several machining operations. In the article "Dimensioning to Control Sizes and to Reduce Scrap Loss," see page 108, S. C. Bliss cites several examples of errors in setting dimensional tolerances with resultant scrap losses. He also lays down some simple rules on how to do the job correctly.

Spring Material Substitutes

The necessity for substituting for steel springs in many applications by other resilient materials, some old and some new, has stimulated the study of more basic qualities than mere size and strength of a coil of spring wire. Wood and plastics, for example, are now proving satisfactory in applications where steel was formerly used according to W. W. Boyd on page 112.

Pipe Stress Charts

An enormous time saver for those engaged in hydraulic design are the two charts for deriving stress in piping under internal pressure. The formulas on which these charts are based are well known but so far as we know have never been put in this form before. H. W. Hamm has done this, as presented on pages 125 and 126.

WHAT'S COMING

Highly Stressed Studs

Stud fastenings are relatively simple to design, but not when weight must be a minimum and stresses are high. In March P.E. Russell Anderson of the Aluminum Company of America presents a detailed analysis of the design of such joints. Many readers will find a wealth of information and ideas in this remarkable article which also describes a new type of thread.

Designing With Plywood

Plywood was losing ground as an engineering material until the war came along because most requirements can be filled by metals and their alloys and because engineers have been trained to work with metals instead of wood, since shortages of metals forced use of other materials, among them plywood, it became necessary for engineers to familiarize themselves with methods of fabricating with these materials. Various approved methods and kinks in designing with plywood are to be described and illustrated in March P.E.

Commercial Tolerance for Springs

Many spring manufacturers have agreed to certain commercial tolerances, but some do not hold to them. This is partly because designers do not appreciate the necessity for larger spring tolerances than can be used in working with materials. In an effort to end the existing confusion, Harold Carlson, chief engineer of the Lee Spring Company, presents easily readable commercial tolerances in tabular form, based upon inherent variations caused by automatic spring coiling machines and manufacturing methods.

Mining—Number One War Industry

The mineral products of the earth are the prime necessities of war...and peace

THE SURFACE of the earth provided primitive man with the things he needed for his meager existence but civilization really began when he became curious about its interior. This curiosity has brought us a long way. For the earth has yielded—out of its deep recesses—all the raw materials of modern industry. And today, in the grueling race of production, our mining industry is providing the raw materials upon which depends our survival. Our mines and quarries must supply a long list of materials without which a successful war cannot be fought.

Take steel, for example. War without steel is inconceivable. Steel starts with iron ore, limestone and coke. These are products of mines and quarries. It takes power and heat to get these materials out of the ground, to refine them and to transport them to the point where processing begins. All the subsequent operations culminating in the steel ingot, shape or plate, and in moving the final product to the point of use require power and heat.

The major source of this power and heat is coal.

Production of a ton of steel, it has been stated, requires two tons of coal. Smelting of the pig iron alone, 60,000,000 tons in 1942, required the coking of some 75,000,000 tons of coal. Pig output is expected to rise to 68,000,000-70,000,000 tons in 1943, carrying coal consumption up to 85,000,000 tons. At the same time, output of steel ingots is expected to rise from 87,000,000 to 97,000,000 tons. Think what this means in terms of power and heat.

Another vital metal is copper. Modern armies need copper. This point is dramatically illustrated in a recent memorandum by Robert P. Patterson, Under Secretary of War, in announcing the release of 4,000 men from military service to return to the mines and increase copper production. "In a single minute of combat", Mr. Patterson declared, "a flight of 50 fighter planes shoots away 7 tons of copper. A 37-mm. anti-aircraft gun uses up a ton of copper every twenty minutes it is in operation. Six hundred pounds of copper go into every medium tank, and a ton into the engines and airframe of a Flying Fortress. The Signal Corps alone needs 5,000 tons of copper every month for radio and telegraphic and telephonic equipment. An army without copper would be an army without speed, maneuverability or firepower. It would not last a day in battle".

Seven tons of copper for one minute of combat by 50 fighter planes means from 200 to 700 tons of ore, depending upon its grade. Small wonder that the War Department was willing to release drafted miners from military duties to produce more copper.

But other metals are equally important in war: tungsten, nickel, manganese, chromium, vanadium and molybdenum for alloy steels; zinc for brass and die castings; tin for bronze and bearings; aluminum and magnesium for aircraft; lead and mercury for ammunition; silver for electrical equipment, bearings and solder, and so on. Even relatively insignificant non-metallics, like mica and diamonds, suddenly assume critical importance.

And let us not lose sight of the fact that without adequate energy, i.e., heat and power, production, processing, transportation and the relative comforts to which we have become accustomed would be impossible under war conditions. Coal is the major source of energy in the United States. It supplies more than half the total in normal years.

The railroads of the country alone used 110,000,000 tons in 1942 to move freight and passengers and service their facilities. Utilities consumed over 68,000,000 tons in the production of electric power. Over 135,000,000 tons of coal were consumed last year in maintaining the level of heating comfort necessary for the maintenance of efficiency and morale. The consumption, this year, will be even greater.

In short, the mineral products of the earth are the prime necessities of war.

The nations that control the world's mineral resources and make the most efficient use of them will win the victory.

Before the war, the British Empire and the United States together controlled probably 75 per cent of the world's mineral production. This would have been a most potent weapon in the United Nations' arsenal if the whole strategy of Axis expansion had not been influenced by mineral objectives. Addressing the American Zinc Institute on the subject last April, E. W. Pehrson, of the U. S. Bureau of Mines, estimated that the Axis had improved its position in world mineral resources in the following percentages: iron ore, from 6 to 46; steel production capacity, 20 to 34; petroleum, 1 to 7; coal, 27 to 53; copper, 5 to 10; lead, 7 to 22; zinc, 16 to 27; tin, 1 to 72; manganese, 2 to 30; chrome, 3 to 30; tungsten, 6 to 60. In the light metals, areas now Axis-controlled produced in 1940 54 per cent of the world's aluminum, 49 per cent of the bauxite (the principal source of aluminum) and two-thirds of the magnesium.

Despite these gains, the industrial war power of the United Nations still can outweigh that of the Axis by a considerable margin. It already has begun to surpass it. The problem is to convert quickly our potential mineral resources into implements of war. In this conversion, a heavy burden of responsibility has been placed on the mining industry of the United States as the largest producer of many metals, minerals and fuels. In fact, the United States mining industry began to go on a war basis a year before Pearl Harbor. The curves of demand for domestic copper, lead, zinc and other metals began to rise sharply in 1940, and were paralleled by a rising coal production.

How well the job has been done cannot be revealed in accurate figures in many cases because of censorship. In metals, however, some idea of production gains can be indicated in comparative terms. United States copper production, for example, is breaking all previous records. Aluminum capacity will be more than seven times its annual peace-time average. Magnesium plants now building will have a capacity 100 times the largest yearly before-the-war figure. Molybdenum, of which the United States has the largest single mine in the world, is being made available in record quantity. Zinc, lead and mercury are surpassing expectations in meeting wartime demands, and tungsten, chromium, manganese, antimony and iron and steel are being turned out in record-breaking quantities.

Bituminous coal production in 1942 was 580,000,000 tons, the greatest in history, valued at more than $1,300,000,000 at the mine. Some 430,000 or more men were employed in 1942 and received at least $750,000,000 in wages. Bituminous production in 1939 was 394,855,000 tons, while the output for 1943 is forecast at approximately 600,000,000 tons — another new United States record. The 1942 anthracite output was 59,961,000 tons, valued at over $270,000,000 at the mine. The industry employed some 85,000 men and paid out at least $180,000,000 in wages. The 1939 production of anthracite was 51,487,000 tons, and the forecast for 1943 is 65,000,000 tons or more.

This is the eighth of a series of editorials appearing monthly in all McGraw-Hill publications, reaching more than one and one-half million readers, and in daily newspapers in New York, Chicago and Washington, D. C. They are dedicated to the purpose of telling the part that each industry is playing in the war effort and of informing the public on the magnificent war-production accomplishments of America's industries.

Marshalling the Western Hemisphere's mineral resources, the United Nations have been the beneficiaries of the diversified resources of two continents — in particular of Canada's nickel and coal, Mexico's lead and antimony, Chile's copper, Bolivia's tin, Peru's vanadium, Brazil's iron, and Venezuela's petroleum. With other United Nations contributing their share of metals and fuel, the grand total is an impressive array of potential munitions and matériel to lend assurance of certain victory over the Axis. Sheer weight of metal, properly used, will win the war, and our mineral industry will have played an indispensable and essential part in the inevitable outcome.

James H. McGraw, Jr.

President, McGraw-Hill Publishing Company, Inc.

PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

To Help Our Neighbors to the South

NATURALLY, BECAUSE OF CONDITIONS created by the present war, the United States and the countries of South America are being brought closer together. Special efforts are being made by our State Department to establish better understanding, both commercial and political, between the peoples of the two continents of the western hemisphere. Leading export houses and manufacturing companies of the United States are cooperating and South American countries in general are welcoming the opportunity for developing increased trade with the United States.

It is to the mutual interest of the peoples of South America and of the United States that the closer ties between them continue and grow even stronger after this war is over. All indications are that this objective will be achieved but nothing must be left undone that might help to cement more firmly our relationships with Latin American countries. A highly important contribution would be one that would bring about a better understanding by Latin Americans of our standardized manufacturing technique. The almost total absence of standardization in their industries has been the greatest single hindrance in the development of our exports of electrical equipment, railroad rolling stock and much other machinery.

The reasons why South American countries adopted non-standard equipment point to the methods to be used to combat the situation. Many years ago German sales engineers, realizing that their manufacturers could not compete on a cost basis with the goods produced by American mass manufacturing methods, resorted to every possible means to induce Latin American engineers to specify non-standard equipment. Thus it came about that 40 cycle generators, 140 volt generators, non-standard power plant equipment of all kinds, and non-standard railroad track gages, were sold to South America. This required electric lamps, motors and most other electrical units to be non-standard. United States firms, and to a large extent British firms also, could not furnish non-standard material as cheaply as the Germans whose manufacturing methods were more adaptable to the production of special items in small lots. As was to be expected, Germany began to charge exorbitant prices for the non-standard goods she furnished, a condition which existed until the outbreak of the present war.

Latin Americans have now awakened to the fact that non-standard equipment is highly expensive and impedes progress. They are anxious to get rid of not only the chaotic situation that has resulted from the great variety of non-standard power systems throughout South America, but also the non-standard railroads and all other non-standard equipment.

It would be a great help to Latin American engineers and industrialists if they had available, printed in Spanish and Portugese, copies of standards such as those of the American Society for Testing Materials, the Society of Automotive Engineers, the Boiler Code and other standards of the American Society of Mechanical Engineers. Designers and metallurgists of the United States will perform a great service if they will induce their professional societies to have their standards translated and printed for South American use. The American Standards Association is contemplating doing this and is studying the matter seriously.

WARTIME DESIGN NEWS

MORE PATENT REFORM

The attempts at patent reform which during 1942 led the Senate Patents Committee through a voluminous record largely concerned with international cartels did not end with sine die adjournment of the 77th Congress last December.

According to Chairman Homer T. Bone, who, with Assistant Attorney General Thurman Arnold, directed the investigation, the committee will be doing business at the same old stand this session.

Probabilities are the committee will consider essentially the same legislation it had during last year, when its principal fodder was a series of bills allowing the President to acquire patents during wartime, requiring compulsory licensing under certain conditions and tying patent manipulation to the Sherman Act, (PRODUCT ENGINEERING, Oct. and Nov. 1942, pp. 548 and 644.)

Bone's idea is to make last session's nine-volume record a part of the proceedings of the new committee. He hopes to pick up his old skein and weave it into an overall picture of the cartel system. With that picture complete, legislation to cure the evils it discloses can be prepared.

When the 1943 hearings get underway, unfinished business will include an investigation of the Alien Property Custodian of World War I and an opportunity for those who choose to protest any of the 1942 record to do so. Those who plan to object to the 1942 record need have no fear that the hearings will end without a chance to protest. Bone is explicit on that point. They will be well advised, however, to have their cases minutely documented, for Bone plans a chapter and verse trip through the offending sections for them.

Nothing so drastic is in store for the witness whose protest is merely against a principle of patent reform. One man's opinion that compulsory licensing is a dangerous innovation will be regarded as an honest opinion properly expressed.

The committee probably will be the same as in 1942, with five Democrats and two Republicans. This is significant, since it indicates that the final record may not present as varied or complete a picture as Bone would like it to show. The same committee voted last fall not to probe further into international cartels, leaving at least three of Bone's prime examples unscathed. Bone admits that unless the committee specifically reverses itself on the matter, exploration is finished except for that concerning the Alien Property Custodian of the last war.

The angle here is that after the last war, enemy patents which had been confiscated and spread out through American industry largely reverted to enemy control, mostly in devious fashion. Chemical patents, for instance, were sold by the custodian to a foundation which in turn sold them to American industries. Many of these industries were bought by German interests, paving the way for German infiltration of this country's industry. In his march to power, Hitler took over the German interests which had infiltrated American industry, and from that point, patent reformers insist, the whole thing became a field day for the nations we are now fighting. As Bone puts it:

"It is my honest belief that when war came to us, Germany, because of her vast system of business espionage which had been set up in this country through connections with some of our big business men, which was itself a business front, gave the Farbenindustrie—which was a wing of the Hitler government—more practical knowledge of our war potential than we ourselves possessed.

"Farben was Hitler and Hitler was Farben, and the Farben crowd had its tentacles deep into the American business system."

This time, the Alien Property Custodian is not disposing of title to the enemy patents he confiscates under the War Power Act. Instead, he is issuing royalty-free, non-exclusive licenses good for the life of the patent. While the War Powers Act may be repealed by Congress after the war, actions legally taken under it will live on, leaving the licenses in American hands and titles in the Alien Property Custodian, whose affairs will continue for some time after the war—long enough in all probability to cover the 17-year life of any patent concerned. (The Alien Property Custodian's office for World War I was closed in 1934.) This obviates the possibility of the Germans regaining control of the confiscated patents.

Non-enemy patents which fell into enemy control through occupation also have been confiscated. From these issue non-exclusive, royalty-free licenses good for the duration and six months. At the close of 1942, APC had granted 15 of 100 applications for licenses on confiscated patents, and most of the remaining applications were slated for approval. About 20 new applications were coming in weekly. The available file of confiscated patents had reached 50,000.

That the emphasis is on halting further activities by international patent cartels is not surprising. Bone was a member of the Nye committee which in 1934 made a vast study of the munitions industry, and, according to Bone, ". . . turned up evidence of the free flow of technological information to our potential enemies. . . ."

But the emphasis on cartels does not mean that domestic reform is being overlooked. The reasons for this are not entirely public information. It is logical to believe that much of the emphasis on the international cartel angle is there because that part of the record offers so spectacular a way to publicize the fight for patent reform. Lavish charges of international skullduggery which cripple the nation's war effort draw much more public attention than sound, expert opinions that technical revision of the patent law will react generally for the public good. But specifically why compulsory licensing and other largely domestic concerns must be considered by the committee in its professed campaign against international shenanigans is "off the record."

ORDNANCE DERATED

The slash in the Army's ordnance program to free materials, men and facilities for more vital shipping, escort

vessels and aircraft. (PRODUCT ENGINEERING, Jan. 1943, p. 2,) totals about 15 percent overall, according to figures confirmed by Ordnance Department officers.

The curtailment hits tanks, ammunition, guns and vehicles, and affects thousands of contracts and producers. Estimates of the value of affected contracts run as high as $8,000,000,000. Some officers describe these figures as "conservative." Others said they are "about right" for present operations, but subject to change either way before the year's end, depending on the tide of battle.

The tank program went down 20 percent. with heavy tanks hit hardest. Ammunition requirements underwent a 10 to 12 percent slash, anti-aircraft guns and fire control instruments 15 to 20 percent. Trucks and other vehicles suffered an undisclosed reduction.

Effect on the plane program will be production of twice the number and about four times the weight of the 1942 program, which realized 48,000 planes. Merchant shipping for 1943 has been set at 18,000,000 tons. Escort vessels in an amount undisclosed but sufficient to protect the merchant fleet, have "must" status in the program.

In effecting the curtailment, the emphasis will be on reducing rather than cancelling contracts. Some plants, particularly those just coming into production. will be converted from ordnance to the more vital programs.

STANDARDIZATION AGAIN

Cooperation between U. S. and British aircraft manufacturers on standardization and interchangeability has been more or less widespread since our plane production mushroomed more than two years ago to meet war needs. Latest splash in the pool comes from the National Aircraft Standards Committee in reply to overtures made by the British in September 1941, for parts standardization. NASC has sent a list of all its

Official Photos U. S. Army

First pictures of captured enemy small arms. Above, Maj. Gen. Levin H. Campbell, Jr., Chief of Ordnance, examines a Japanese grenade thrower, whose trigger he is pulling. This 50 mm., smooth bore weapon throws a 1½ lb. grenade 100 to 150 yards. Base may be rested against tree stump or the ground. U. S. grenade throwers are larger caliber, have many times the range. Top right: Gen. Campbell examines a 7.7 mm., air cooled Jap heavy machine gun. This copy of the French Hotchkiss is of smaller caliber than U. S. heavy machine guns, with less fire power and range. Bottom right: Gen. Campbell squints through sights of German 7.92 mm. air cooled machine gun on anti-aircraft mount. Firing tests showed gun and tripod inferior to U. S. weapons.

standards to the British in return for a file of those compiled by the Society of British Aircraft Constructors which was given American industry more than a year ago. NASC also gave a complete outline of its operations to SBAC, which has not yet acted upon the bid for close cooperation. A similar outline of SBAC operations is awaited here.

NASC describes its present activity in the field as "simply casting about, looking for specific items the need for whose standardization is most feasible." That it is doing anything specific at all toward common standards is reasonably concrete evidence that it expects the plan to go through — to a greater extent than mere formality.

First specifications attacked by NASC with a view to international standardization were those for a series of cockpit handwheels to operate control tabs. These British standards are now being circulated among NASC's 28 member companies to determine the desirability of their adoption as national aircraft standards.

NASC says it is planning, when a working agreement is reached, to consider for adoption for American use any of the SBAC standards for which it has developed no corresponding specification. The British may be expected to reciprocate. This policy would not mean that manufacturers of both countries would be required to use any existing standard merely because its own body had not yet prepared one for the part in question. Where no conflict existed, however, such cross-acceptance of existing standards would serve the twin needs of saving time and promoting interchangeability. Canada and the other nations of the British Commonwealth which use both American and British planes obviously will benefit.

The program could logically include most of the conventional appliances with which combat planes are equipped, including small assemblies, without infringing anyone's rights in the matter of overall design. Fasteners, seats, gun mounts, control levers, pulleys and similar appliances probably will be studied if the plan goes through.

The American Standards Association has assured its cooperation, and the U. S. services approve as well. NASC and British officials here expect something tangible to come out of this attempt at a get-together.

NEW MANPOWER PLAN

For the time being, the Replacement Schedule has become the device by which draftable workers will be drawn into the armed services.

This latest plan was brought out by Selective Service after War Manpower Commission took over the Manning Table plan which Selective Service put together to provide for orderly withdrawal of key personnel.

The Replacement Schedule consists of two parts, a Replacement Summary and a Replacement List. In the former, employers list job titles by plant department or other operating unit. Listed with each title is the number of women, nondraftable men and draftable men employed thereunder. Thus, the Summary presents a condensed breakdown of jobs and workers.

On Replacement Lists are carried only those employes who actually are liable to be replaced. Each is listed by name and job title, year of birth, draft classification, draft board and order numbers and the number of months before the employer will be prepared to replace him. Normally, the men who will be replaced soonest are those whose jobs require the least training. Generally, also, the first to be replaced among two or more men working on the same job will be those who would first be available were there no occupational considerations. Single men are listed ahead of equally replaceable married men. Lower order numbers determine precedence on the Replacement List among two or more equally-replaceable workers.

Governed by these limitations, Replacement Lists will be prepared so that, under a given job title, men will be listed in ascending order of the deferment requests made for them, i.e., shortest deferments first, etc.

In addition to its simplicity, the Replacement Schedule differs from the Manning Table in that it need not be validated by WMC. The Replacement Schedule is effective upon validation by the State Selective Service director concerned. Its life is six months, after which a renewal must be submitted and validated.

Having validated a Replacement Schedule, the state Selective Service director assigns it an acceptance number which may be reproduced on every 42A or 42B form submitted by the employer to claim occupational deferment for a worker. The number is notice to the draft board that the worker is part of an approved withdrawal scheme and should be treated as such.

Actually, draft boards are still autonomous, and the federal government may only recommend criteria of classification to them. It is to be expected, however, that draft boards will go along with the plan, and in doing so, they will eliminate one of the principal abuses of the Selective Service system as it has operated for the last two years. Employers who use the Replacement Schedule will no longer have much reason to fear varying decisions on similar cases by different boards.

X-RAY EYE GOES TO WAR

WPB is studying a plan to boost production of certain ammunition components by the use of zinc and aluminum die castings. Governing the program is the proviso that x-ray apparatus of at least 1,400,000 volt capacity shall be used to inspect the castings to obviate possibility of internal flaws which might result in faulty ammunition. Only producers whose methods stand up under rigid inspection will contribute to the program.

Every piece produced in sample runs will be inspected by x-ray, and specified numbers of samples from production runs will be tested in the same fashion. Die casting allows exceptionally fast production of certain components.

MATERIALS

List C of Order M-126, specifying equipment which may be manufactured from steel or stainless steel for military use, has been revised to include a number of products previously prohibited. (Amendment 1 to amended order.)

Hardwood consumption for 1943 has been estimated at 5,670,000,000 ft. Production is 10 percent under that for the corresponding season last year and mill stocks are below normal.

Order M-260 places all acrylic resins and acrylic monomer, including such products as Lucite, Plexiglas, Acryloid and Crystalite, under rigid allocation control.

Carbon steel made in electric furnaces comes under complete control under order M-21-a as amended. Previously the order affected only alloy iron and steel.

TRENDS

WPB announced a system of supplementary temporary quotas to allow steel warehouses to rebuild their stocks. Preference ratings assigned warehouses have fallen behind the general run of ratings, causing depletion of stocks. . . . A saving of 30,000 tons of cast iron will be effected by manufacture of 1,000,000 ceramic fireplace grates. . . . Purchase of aluminum and magnesium mill shapes listed on Form PD25A is not authorized on PRP certificates for the first quarter of 1943. Orders must be placed with the mill which will ask approval of shipping schedules from WPB's Magnesium and Aluminum division. The change is to facilitate transition from PRP to CMP.

Relative Merits of Materials Used for Light-Weight Structures

FLETCHER PLATT
Stress Analyst, Fleetwings, Inc.

The design of planes made of aluminum, stainless steel, carbon steel and plywood has demonstrated that there is no one material that can be regarded as superior to all others for light-weight construction. The author explains why and sets forth some of the major considerations when attacking the problem of selecting the material to be used.

BECAUSE of the extremely heavy demands that war producton has placed on the manufacturers and suppliers of structural materials, it has become necessary to investigate the possibility of using any one of numerous materials in the manufacture of aircraft and all other types of structures. Many excellent papers have been written on the points of superiority of a given material but because of the complexity of the variables involved, it is neither possible nor logical to claim for any one material an overall advantage over all other materials. Each material has its own peculiar characteristics and points of superiority and deficiency. Regardless of the material used, the design problem is always to take every possible advantage of the points of superiority of the material and compromising to compensate for the properties in which the material is inferior. However, no specific formula or group of formulas can be presented which will evaluate definitely the merits or demerits of a particular material.

The engineering department at Fleetwings has been designing and manufacturing over the past years

Table I—Comparison of Three Materials Covering a Wide Range of Densities

	Spruce	24ST Dural Sheet	18:8 Full Hard Stainless Steel
Ultimate Tension	9,400	62,000	185,000
Tension Yield (0.2 percent)	.....	40,000	140,000
Tension Elongation, percent	.....	10–12	8–9
Ultimate Compression	5,000	62,000	170,000
Comp. Yield (0.2 percent)	4,000	40,000	105,000
Modulus of Elasticity	1.3×10^6	10.3×10^6	26×10^6
Ultimate Shear	750	37,000	100,000
Bearing Strength	4,800	90,000	195,000
Density, lb. per cu. in.	0.0156	0.100	0.283

Table II—Percent of Structural Elements Designed to Resist Various Types of Possible Failure

The structural weights include such structural items as spars, skin, ribs, frames, longerons, struts, etc.; fittings are not included in this summary.

Airplane Basic Material	A Plywood	B Dural	C Stainless Steel
Designed Gross Weight, lb.	2,200	1,700	4,500
Structural Weight, lb.	338	395	869
Designed for Tensile Strength	0	0	0
Designed for Compressive Strength	24	30.4	56.7
Designed by use of Beam Formulas	42.3	0.6	0
Designed as Shear Members	0	0	0
Designed against instability in compression or shear	33.7	69	43.3

numerous airplane structures in stainless steel, chrome-molybdenum steel, Dural and plastic-bonded plywood. Each of these materials has been found to possess, in the experience of Fleetwing design engineers, definite advantages when used for one or the other of various structures in aircraft. In each case the character of the specific structure, the loads to which it will be subjected, the conditions that it will meet in service, and the requirements for production will profoundly affect the approach to the design problem.

Comparisons on Basis of Density

If the weight of the finished structure is of paramount importance, as in the design of aircraft, it is only natural that the first consideration in the selection of the material should be given to a comparison of possible materials covering a wide range in density. Three materials that are representative of the complete range of densities found in structural materials are (1) wood (spruce), (2) Dural (24ST), (3) stainless steel (18-8). Table I gives the principal physical characteristics and properties of each of these materials. In each case the tension yield and compression yield points were obtained by the 0.2 percent offset method.

It was formerly thought that the most important factor in the selection of a material for the design of a light-weight structure is the strength-weight ratio. This erroneous idea assumed that it was necessary merely to divide the tensile strength of the material by its density and select the material with the highest strength-weight ratio. Actually, this method is misleading in its results and should never be used as the basis for comparing structural materials for aircraft construction, or other light-weight structures, without giving proper considerations to all of the major factors involved, as will be brought forth in this article.

The most logical approach to the problem of determining the relative merits of the various materials that might be used is to analyze the design of similar structures that have been built and tested previously and to list the specific strength properties on which the design calculations were based and also the type of design equations used. Table II presents a summary of the results of such analysis of three airplanes made of stainless steel, Dural and plywood and shows the relative extent to which the various members of the structure were designed to resist tension, compression, bending, shear and instability in compression or shear.

Airplane C referred to in Table II is basically a stainless steel construction. The wing consists of two outer panels and a center section. Each outer panel has a D-spar nose box with a smooth skin, corrugations in tension and corrugations in compression carrying the bending loads and a stiffener-skin web carrying shear. The ribs are stamped 18-8 stainless steel with flanged lightening holes and beads.

The aft section of the wing panel is fabric covering over truss type ribs. Movable surfaces including aileron, flap, rudder and elevator are all D-spar fabric covered structures with stainless skin to carry bending, torque and shear. Fixed tail surfaces are of skin-corrugation torque box construction. Fuselage is chrome-moly tubing from the rear cockpit forward and is stainless steel truss and semi-monocoque aft to the tail cone.

Airplane B is mainly of Dural construction with a D-spar torque box wing including heavy extruded flanges to carry bending. No stringers are used in this box. Ribs have stamped lightening holes and stiffeners. The aft section of the wing is fabric covering over stamped ribs. Fuselage is pure monocoque except for longerons in the region of the cockpits. Fixed surfaces are typical Dural construction. All movable surfaces are stainless steel similar to those in airplane A.

Airplane A is fabricated largely of poplar plywood. The wing has a single main spar of maple cap strips and solid poplar core. The ribs are routed plywood and no spanwise stringers are used. Skin is carried aft to aileron and flap and the box is closed by a false spar. Fuselage is part monocoque except for stringers in region of cockpit. All fixed and movable surfaces are plywood covered.

A study of the data in Table II reveals a number of interesting facts:

(1) Exclusive of fittings, none of the structural members in any of the three airplanes were designed on the basis of the tensile strength required. Admittedly, numerous elements of an airplane structure are subjected to tension but their tensile strength requirements do not determine their dimensions. These are calculated on the basis of required stability, joint requirements and similar considerations.

(2) More of the elements of the Dural airplane structure that was analyzed were designed against failure through instability than is the case in the stainless steel airplane. It should be explained that in the stainless steel design analyzed in Table II, the sheets subjected to compression were corrugated in order to strengthen them against local instability, while in the design of the plane made of Dural, the sheets were not stiffened.

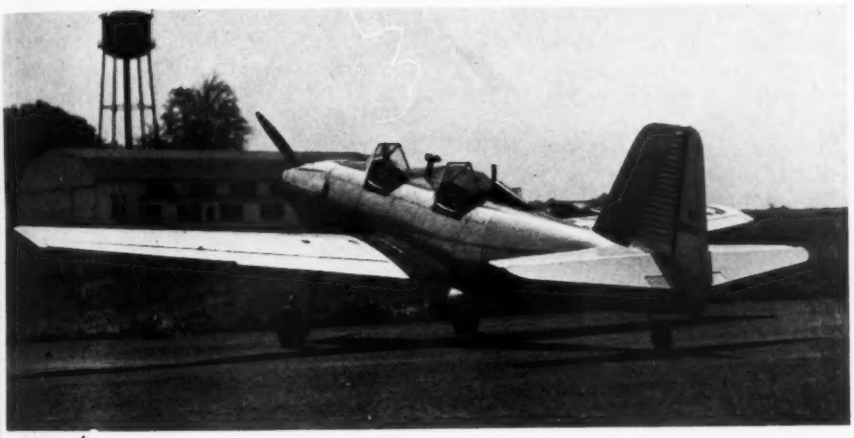
(3) Because of the many solid spars used in the plywood airplane structure, a large percentage of the elements were designed by the use of the beam formula, $S=Mc/I$. In the case of the Dural

airplane, it was considered that because the Dural spars have light shear webs, the cap strips in compression and tension develop the necessary resisting moment and the design calculations were made accordingly, instead of applying the conventional beam formula.

(4) No element of any of the three airplane structures referred to in Table II was designed on the basis of the ultimate shear allowables of the material. Modulus of elasticity, compressive strength and other properties were the controlling factors.

Table II clearly demonstrates that strength-weight ratios in themselves are misleading. Consideration must be given to the relative densities in conjunction with other properties of the material. The data given in Table II apply numerically only to the three structural materials selected but the principles demonstrated will apply to all materials that might be compared.

Fairchild all-plywood monoplane



Dural primary trainer designed and built by Fleetwings. The wing skin is spot welded to the ribs

Stainless steel army basic trainer BT 12, designed and built by Fleetwings. It is first stainless steel plane that was produced in quantities.

Major preliminary considerations before a material for an aircraft structure can be selected are (1) load requirements, (2) limitations that might be imposed by the size and location of the various elements of the structure and thereby impose a limitation on overall dimensions, (3) compromise between weight and cost of fabrication. External loads are determined according to the performance specifications for which the airplane is to be designed, and, therefore, may be considered a fixed quantity as far as the structural design is concerned.

Limitations on the size of an airplane structure are determined by the aerodynamicist, but some compromise is usually made between the aerodynamic efficiency and the structural efficiency, this being necessary. The location of the structural elements is directly determined, to a large extent, by the design engineer, their locations being largely affected by the positions of various pieces of equipment. For example, the position of the engine will determine the location of the engine nacelle and engine mounts, these in turn establishing the location of various elements of the wing structure. Careful planning and arrangement of such items will keep structural efficiency high. To accomplish this effectively it should be decided at the outset of a new design project whether weight, and consequently performance, should be favored over the cost of fabrication and adaptability to large scale production, all of these elements interlocking.

With these major factors fixed, the problem of selecting materials of construction can then be studied. It can be assumed that materials in each density of the three classes of density—wood, aluminum and steel—are equally available in sufficient quantity. Substitutes are already being developed to replace the materials that have been mentioned in this article. For example 18-8 stainless steel may be replaced by low alloy or non-critical alloy steels. Dural can be replaced to some extent by magnesium alloys. Poplar and Douglas fir may replace spruce. The selection of a certain density material may then be based upon its adaptability to the limitations imposed, as previously mentioned.

One of the major structural characteristics that will influence the selection of the material to be used is local instability or buckling. As mentioned, no definite weighted average is possible without skillful design. The possibility

of local instability or buckling being the cause of failure poses the problem of using the material selected in such a manner that full advantage is taken of its properties and physical characteristics in order to give the structure maximum resistance to local instability or buckling. Thus, regardless of the material selected, the design of the structure must be modified to suit, particularly with reference to the strength of the structure to resist failure through instability or localized crippling, which is a major factor.

Instability

When a member is loaded in compression it can fail in three ways: (1) by crushing, (2) by general instability, such as a column failure, or (3) by local instability. Resistance against crushing is a function of the ultimate compression strength of the material. Resistance against failure through instability, such as a column failure, is a function of the elastic modulus of the material, its strength properties in compression, and the cross-sectional dimensions of the column or elements under compression.

It is interesting that for equal weights of structure, the increased cross-sectional areas gained by the use of a lower density material may or may not be an advantage. If, for example, the outside dimensions of the cross section of a column are restricted, as is usually the case in aircraft structures, the use of a lower density material will not permit an increase in the outside diameter of the column. Assuming a tubular column as a simple illustration, the lower density material will result in increased wall thickness, but this will decrease slightly the value of ρ and thereby increase the L/ρ value of the column, that is, its slenderness ratio. This is a disadvantage although the magnitude of change is only slight. On the other hand, if the outside dimensions of a tubular column are unrestricted, the advantage is decidedly in favor of the lower density material being considered. This will enable an increase in the outside diameter of the column and thereby greatly increase its moment of inertia and the value of ρ and hence appreciably decrease the slenderness ratio.

Failure through local instability of the material or construction is always a function of the gage of the material and its modulus of elasticity, these two factors together with the structural dimensions, determining the critical stress at which local instability occurs.

The critical stress at which local instability occurs in panels can be expressed by the equation

$$f_{cr} = KE\,(t/b)^2 \qquad (1)$$

In this equation f_{cr} is the critical bucking stress, K is a constant depending upon the panel dimensions and fixity, and b is the loaded edge for a sheet under compression, or in the case of a panel subjected to bending moments, it is the edge along the cross-section which is resisting the bending moment. In the case of panels subjected to shear, b is the length of the shorter edge of the panel. All of the units in Equation (1) are pounds and inches. By substituting P/A or P/bt for f_{cr} and solving for the load P Equation (1) becomes

$$P = \frac{KEt^3}{b} \qquad (2)$$

From Equation (2) it is obvious that for a given value of b the load P is proportional to the modulus of elasticity E times the cube of t, the thickness of the sheet, that is,

$$P \sim Et^3 \qquad (3)$$

For each material there is a probable minimum practical gage thickness and likewise a probable maximum practical gage thickness. Therefore, using Equation (3) it is a simple matter to tabulate the relative load carrying capacity of the three materials, plywood, Dural and stainless, with reference to their relative capacity to resist failure through local instability. These values have been tabulated in Table III. Although in special cases the limiting maximum and minimum gage values used in Table III are exceeded, the table does give a clear indication of the higher load carrying capacities of wood over Dural and the superiority of both these materials over stainless steel insofar as strength against failure through local instability is concerned. However, the table clearly indicates that although wood has a certain advantage in allowable buckling load for the minimum gages, this advantage is less pronounced in heavier gage structures where loads are heavier. There are also other considerations that enter into the problem such as the effect of fitting attachments, the relative ease of locally stiffening either Dural or steel panels by means of corrugation or the addition of stiffeners, and similar means by which the advantage of wood over the metal is largely offset.

Considering all of the factors, it appears that the lower the structural loading, and hence the smaller the gage of sheets used, the greater will be the advantage of the low density material, wood. Conversely, under higher loading, the higher density materials offer greater possibility for efficient structural design against failure through local instability. It is to be noted that the stainless steel airplane referred to in Table II was built in competition with similar ships made of Dural, the two ships designed to have an equal structural weight. Both ships were medium loaded airplanes, 18.4 lb. per sq. in. wing loading, and the comparison of the two planes clearly points to the possibilities of achieving light weight when using high density material, if the design is proper.

It can be concluded that because of the large variety of stress problems, types of designs and the character of failures, it is impossible to claim that any given material will have an overall advantage. Equally efficient aircraft structures have been designed in wood,

Table III—Relative Load Carrying Capacity as Limited by Local Instability

	Prob. Minimum Pract. Gage In.	Density lb./cu. in.	Rel. Weights lb./sq. in. Surface	E	t^3	(Et^3) Rel. Load Carrying Capacity	Rel. Load Carrying Capacity/ lb. Weight
Birch Plywood	0.0625	0.026	0.00163	2.25×10^6	244×10^{-6}	550	338
Dural — 24ST Sheet	0.020	0.100	0.0020	$10\times3\times10^6$	8×10^{-6}	82.5	41
Stainless Steel — Sheet	0.006	0.283	0.0017	26×10^6	0.216×10^{-6}	5.6	3
	Prob. Minimum Pract. Gage In.	Density lb./cu. in.	Rel. Weights lb./sq. in. Surface	E	t^3	(Et^3) Rel. Load Carrying Capacity	Rel. Load Carrying Capacity/ lb. Weight
Wood — Poplar Plywood	0.500	0.0156	0.0078	1.3×10^6	0.125	162,000	2,080
Dural — 24ST Sheet	0.1875	0.100	0.0188	10.3×10^6	0.0066	68,000	3,630
Stainless Steel — Sheet	0.125	0.283	0.0355	26×10^6	0.00195	50,800	1,430

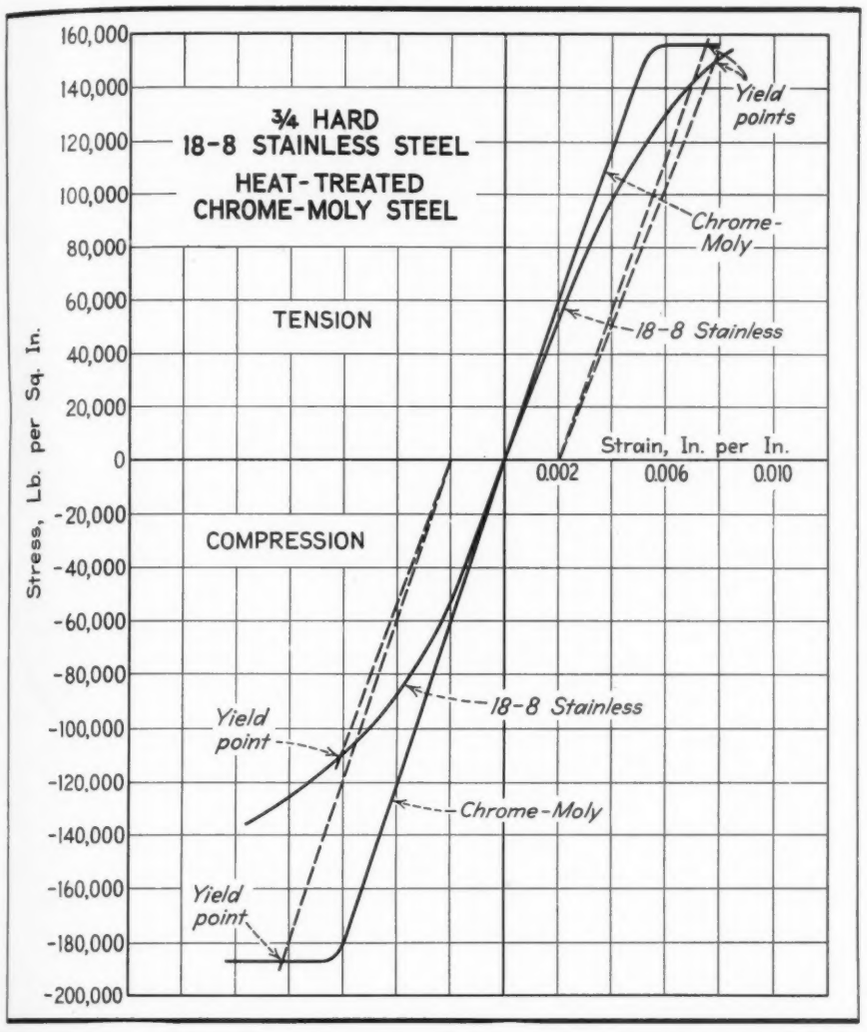


Fig. 1—Stress-strain curves for ¾ hard 18-8 stainless and chrome-moly steel. It is significant that the tension and the compression strain curves are considerably different

Dural and steel, which proves the point that the ingenuity and resourcefulness of the structural designer is a major factor in the problem of designing lightweight structures.

Selection of Allowable Values

Because only a relatively few parts of an aircraft structure are designed as tension members, the tension stress-strain curve of a given material does not enter into the calculations to any great extent. On the other hand, property values as determined by the compression stress-strain curves enter into many of the calculations and, therefore, special study should be made of that curve. Of primary importance is the fact that the compression stress-strain curve is not identical to the tension stress-strain curve. Reliable methods have been developed for obtaining the compression stress-strain curves for thin sheets of various materials as described in the NACA technical report No. 649 "The Pack Method for Compressive Tests of Thin Specimens of Materials Used in Thin-Walled Structures," by C. S. Aitckison and Alfred B. Tuckerman. Typical tension and compression stress-strain curves are shown in Fig. 1, the curves being reproductions of those given in NACA Technical Report No. 615 "Column Strength of Tube Elastically Restrained Against Rotation at the End," by William R. Osgood. The curves in Fig. 1 show in a striking manner that there is an appreciable difference between the compression stress-strain curve and the tension stress-strain curve.

Perhaps the two most important points established by the stress-strain curves are the yield points of the material and its modulus of elasticity. As has been explained, both of these values enter into the calculation of all columns, compression members and elements that must be designed to resist failure through local instability.

Determining the yield point of the material from the stress-strain curve by means of the 0.2 percent offset method, as indicated in Fig. 1, does not give reliable values. It is not a rational method for determining the yield point of the material and is primarily a carry-over from the early methods devised for designing civil engineering structures. To enable the design of the lightest possible structure, as is required in the design of aircraft, it seems advisable to use a more rational basis for obtaining the yield point of the material. The numerical value of the yield point is the basis on which the allowable column stresses are determined, especially in the design of columns in the low-range of slenderness ratios.

In the design of columns, perhaps the best method of determining the allowable stress is to use the column yield stress. This has been defined as "The upper limit of the allowable column stress for primary failure is called the column yield stress . . . the column yield stress is mainly determined by the nature of the stress-strain diagram of the material. When the material has a definite yield point in compression, this value may be assumed for the column yield stress. Few materials, however, have a sharply defined yield point. In such cases it is usually possible to determine the column yield stress as a function of either the tensile or compressive yield stress." A rational method of doing this will be explained.

Another highly important property value entering into the design of all types of structures is the modulus of elasticity. The well-known Young's modulus was established on the assumption that the stress-strain curve within the proportional limits is a straight line. The numerical value of Young's modulus is, therefore, the value of stress at any one point divided by the strain at that point, and hence is the slope of the tangent to the stress-strain curve.

In Fig. 2 the moduli of elasticity as determined from the stress-strain curve in Fig. 1 are plotted for chrome-moly steel and 18-8 stainless steel. To plot these curves it is merely necessary to determine the tangent at various points in the compression stress-strain curve from which the modulus of elasticity at the various stresses can readily be calculated.

The two curves of compression-stress tangent-modulus shown in Fig. 2 have been extrapolated to $E = 0$ by simply continuing the curve to its intersection with the ordinate at zero strain. Extrapolating in this manner assumes that the curve will continue in a straight line or in the same direction to its intersection with the Y axis, at which intersection the value of E will be zero and the corresponding compressive stress will be the ultimate compressive

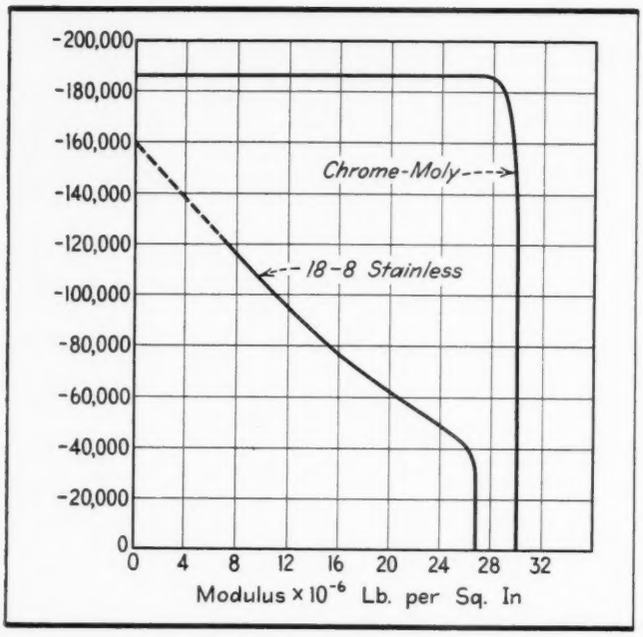


Fig. 2—Compression stress-tangent modulus curves for 18-8 stainless and chrome-moly, constructed from the curves in Fig. 1

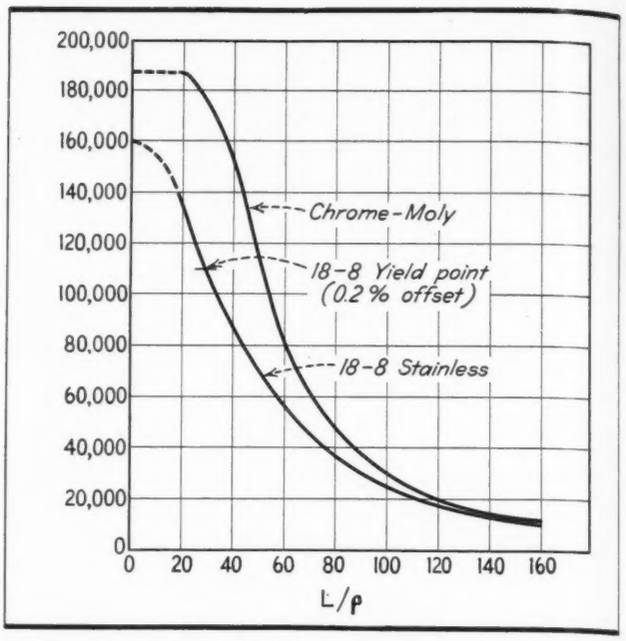


Fig. 3—Column curves for 18-8 stainless and chrome-moly. Error in yield point by the 0.2 percent offset method is indicated

strength of the material. Thus in Fig. 2 the curve for chrome-moly steel intersects the Y axis at a stress of 187,000 lb. per sq. in., while the curve for 18-8 stainless steel intersects the stress scale at 160,000 lb. per sq. in. These will be the value of the column yield point if it is assumed that the column yield point is the stress at which the modulus of elasticity equals zero.

For these two specimens the column yield stress may be considered at 187,000 lb. per sq. in. for chrome-moly and 160,000 lb. per sq. in. for the 18-8 stainless steel. These column yield stresses are above the average for both of these materials and in an actual design somewhat smaller values should be selected.

In Fig. 3 are plotted two curves, the ordinates being the column yield stress, and the abscissas being the corresponding L/ρ values, or the column slenderness ratios. On the curve for the 18-8 stainless steel, the yield point as determined by the 0.2 percent offset method is indicated.

The tangent-modulus curve can also be used to predict an approximate basic column curve for any given material. This is done by replacing Young's modulus in the Euler equation with the tangent modulus for different values of L/ρ throughout the range of slenderness ratios. The approximate basic column curves thus obtained will give more exact results than the Johnson equation or the straight line equation which are usually used in the short column range.

The foregoing discussion serves to emphasize the importance of the compression stress-strain curves and the derived stress-tangent modulus curves when comparing different materials. Tension and compression yield points as obtained by the 0.2 percent offset method are obviously only a vague indication of the structural merits of a given material, and many erroneous conclusions may be drawn if the whole of the stress-strain curve is not studied and analyzed.

The elongation of materials under stress beyond the yield point is another important property in the comparison of materials of the same density. The elongation of a material is an indication of the ability of the material to relieve stress concentrations and avoid fatigue failure. It is also an indication of the workability of the material which is an important factor from the manufacturing viewpoint.

It has been realized for some time that elongation when measured in the conventional way, in tension over a two-inch gage length, will vary with the speed with which the stress is applied. If the tension testing machine is set for a rapid application of load, the ultimate elongation will be somewhat less, while the ultimate load will be greater. Recently, however, it has been proved that another factor enters into the determination of the ultimate elongation. In most materials, the elongation varies greatly at different points along the gage length. Thus it appears that elongation is not a positive value numerically. It is for this reason that structural materials are now being compared on the basis of their respective impact strength or fatigue strength, rather than on the basis of relative elongation. Also, when comparing two metals for ease of forming and similar production operations, bend tests, or better still, the photo-grid method developed by Lockheed should be used, rather than making the comparison on the basis of the ultimate elongation over two inches.

The allowable shear stress to be used in design calculations can most easily be determined by a comparison of the torsion stress-strain curves. Here again, the actual curves should be compared, rather than using an arbitrary yield point or ultimate stress. In fact, in most design problems it is the torsional modulus rather than the ultimate shear stress, which is the major criteria because most of the structural design is on the basis of torsional rigidity rather than shear strength. Because the proportional limit in shear is usually extremely low, it is advisable to base shear and torsional deflection calculations on the torsion stress-strain curves rather than attempting to apply a fixed torsional modulus.

Many other factors enter into the selection of the material to be used in the structural design. These factors include machinability, weldability, ease of forging, suitability for casting, corrosion-resisting properties and many other considerations. A discussion of these properties, however, is beyond the scope of this article, which is confined primarily to the factors governing design calculations for strength and rigidity. It is hoped that further discussion and comment will be presented on this subject and that methods of comparing the factors governing structural design.

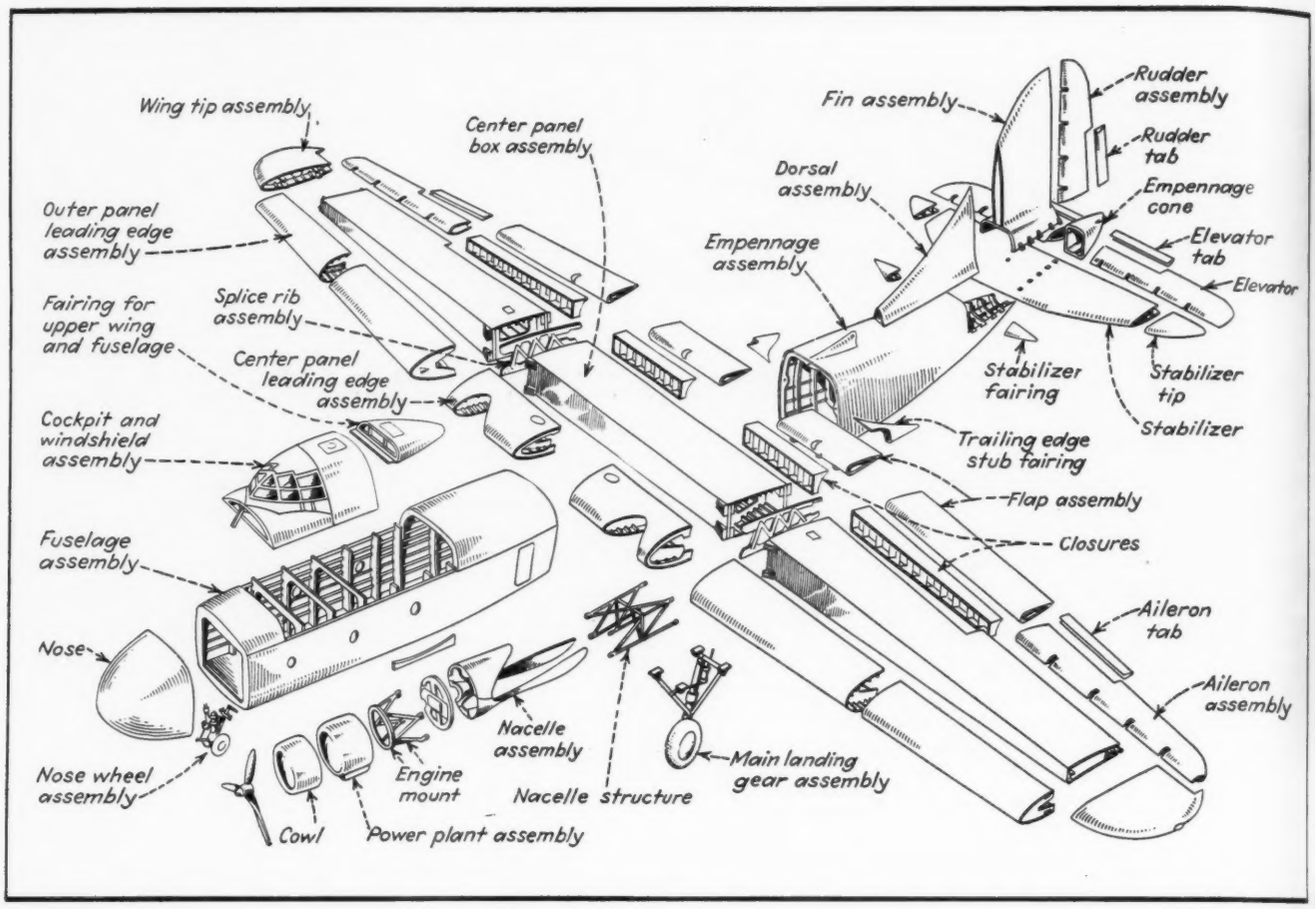
WARTIME DESIGNS . . .

CARGO PLANES OF PLYWOOD SAVE VITAL MATERIALS

TEST FLIGHTS OF THE CARAVAN, recently conducted, indicate satisfactory performance for the first airplane made exclusively of non-strategic materials and designed specifically for transporting military cargo such as parachute troops, air-borne infantry task forces, airplane engines, propellers, litters, shells, guns, reconnaissance cars and jeeps. D. C. Smith, director of transport contracts for the airplane division of Curtiss-Wright Corporation, conceived the idea of an airplane made of wood which could be built in mass quantities to provide needed cargo carriers. Curtiss experts headed by G. A. Page, Jr., director of engineering, and Howard Moles, chief engineer, of the Curtiss Kentucky plant, set up the specifications and developed the design and constructional details for the new molded plywood cargo carrier.

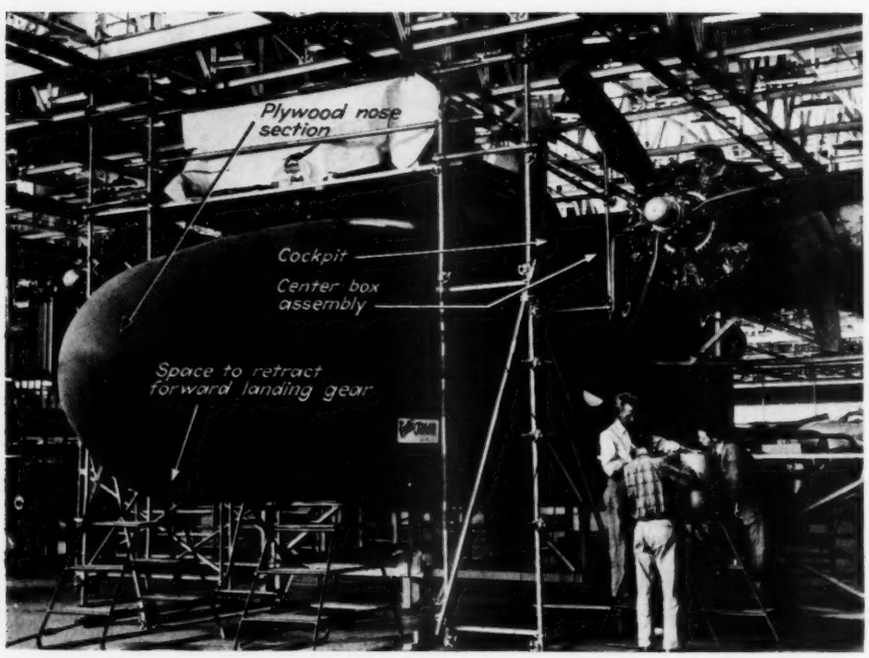
Important performance features of the Caravan are excellent take-off, moderate range and cruising speed, maneuverability, ruggedness, low landing speed, rapid loading facilities and economical operation. While the Caravan was designed primarily for general cargo duty in the United States, it can be used for freight service almost everywhere in the world, particularly in countries where landing fields are small.

Wing span of the Curtiss-Caravan is 108.17 ft. Overall length is 68 ft. Landing gear is the retractable tricycle type to permit maximum maneuverability on small landing fields. When the ship is in the three-point position, the cargo floor is only 36 in. off the ground so that loading and unloading can be easily done. The power plant of the plane includes two twin-row Pratt & Whitney engines rated at 1,200 hp. for take-off, and 1,050 hp. for cruising. Basically, the Caravan is a low-stall freight carrier, designed for frequent stops between short runs of 600 to 700 miles. Since the ship was planned to perform specific tasks that would require landings and take-offs at short intervals from small and undeveloped fields, speed is not an essential factor and is not desirable. Because of its low-speed landing characteristics, the Caravan can be crash-landed in an emergency with the prospect of incurring less damage to itself than would be suffered by cargo planes of other types that must land at higher speeds.

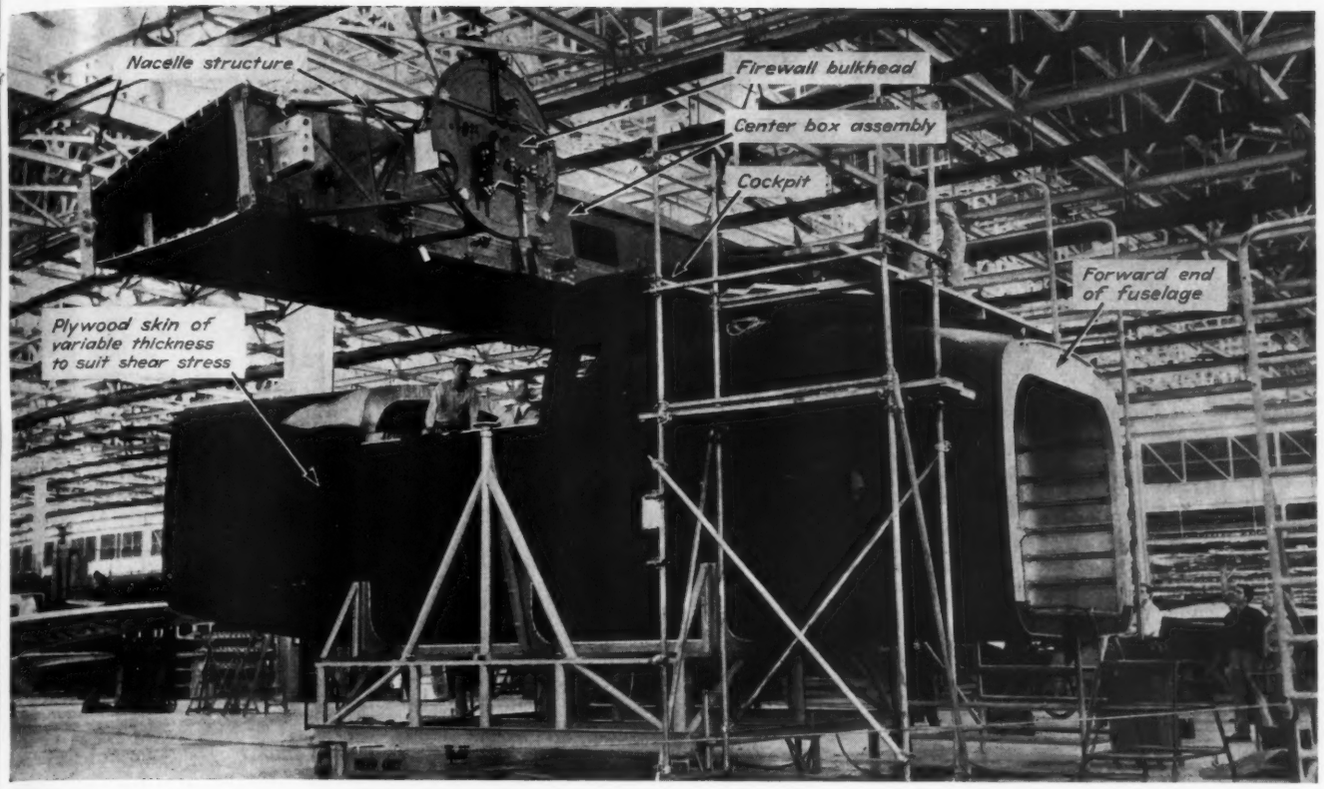


Breakdown of the Caravan's structure into component parts is shown above. With the exception of metal fasteners and plastic materials, construction is entirely of molded plywood, laminates and lumber. To speed production, about 65 percent of the plane is sub-contracted to piano, furniture and other wood-working plants. The Caravan is a high-wing monoplane with conventional two-spar box-type wings. The wing spars are laminated spruce cap strips with plywood webs, internal diaphragms and stiffeners. Plywood used ranges from three-ply at the leading skin edge to nine-ply at the center panel.

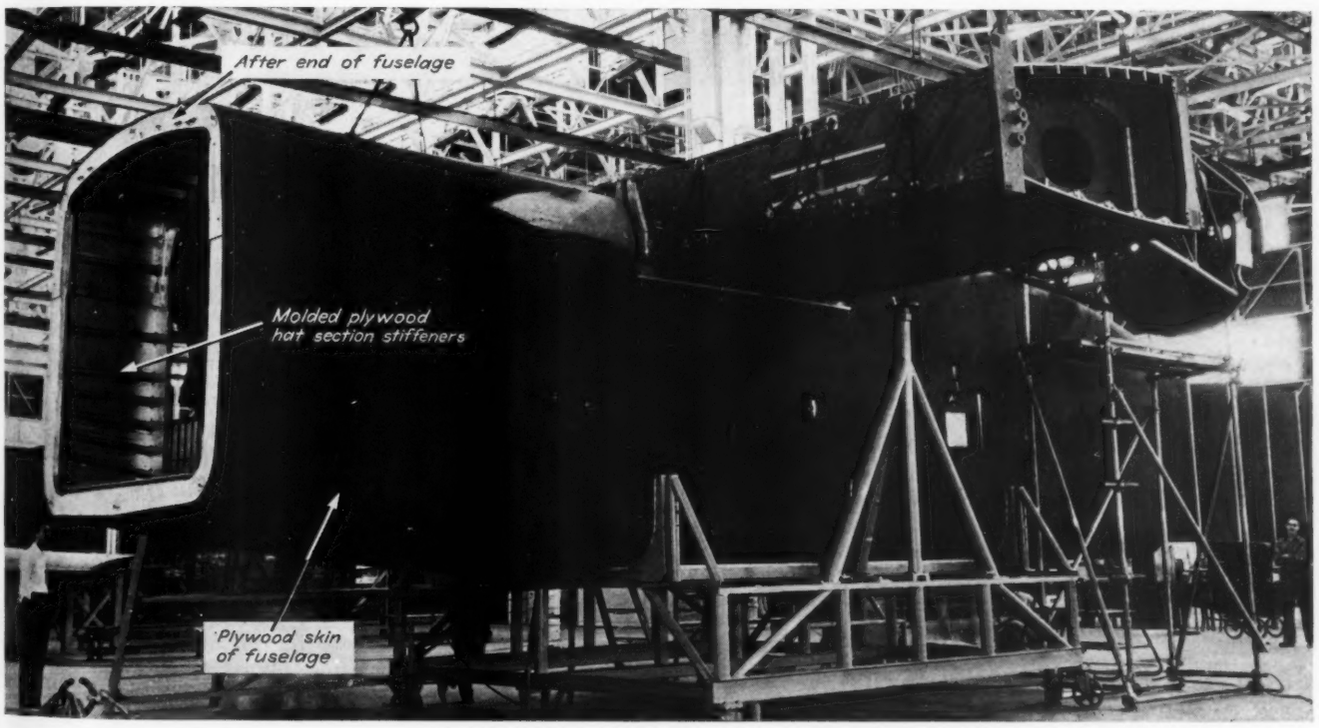
The complete airplane structure was broken up into units of such size that, with the exception of the main fuselage, any component part can be stowed in the cargo space, The plane, therefore, can fly spare parts and replacements to any field where another plane is to be repaired. Only simple hand tools are required to replace any component part of a damaged plane.



View of the smooth plywood nose section attached to assembly of fuselage and center panel with engines mounted, before nacalle skin is put in place. Recess in under side of nose is space in which the front landing wheels and gear retract when plane is in flight. Floor of the Caravan is horizontal when the plane is in a three-point position at a loading ramp. Even an ordinary type ramp is not essential, as a ramp can be built of earth because the landing door is so near the ground.



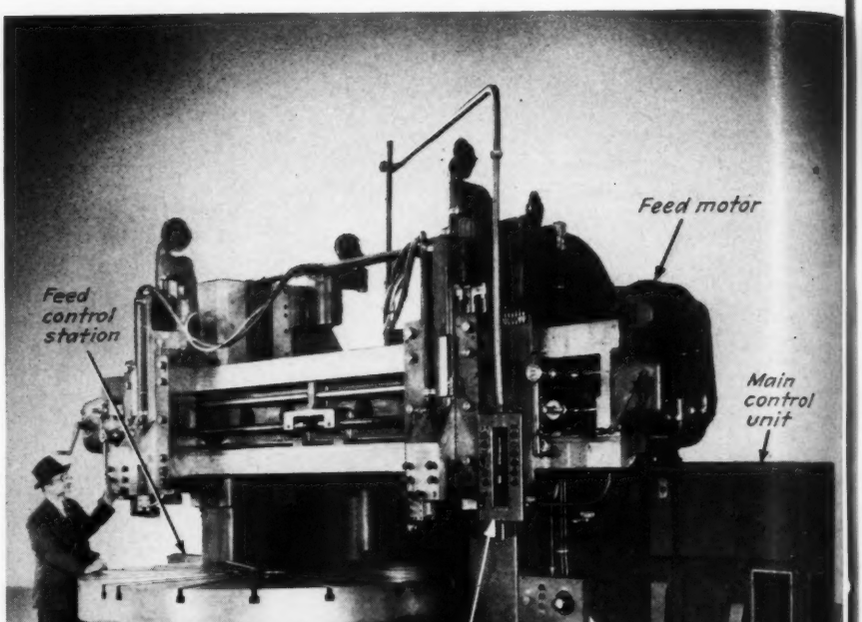
Lowering center panel of Caravan into place for assembly to fuselage. Control compartment of the plane is above the forward end of the cargo space. Under normal operating conditions the crew consists of a pilot and a co-pilot. A radio operator can be accommodated when desired. The Caravan can be equipped to tow gliders.

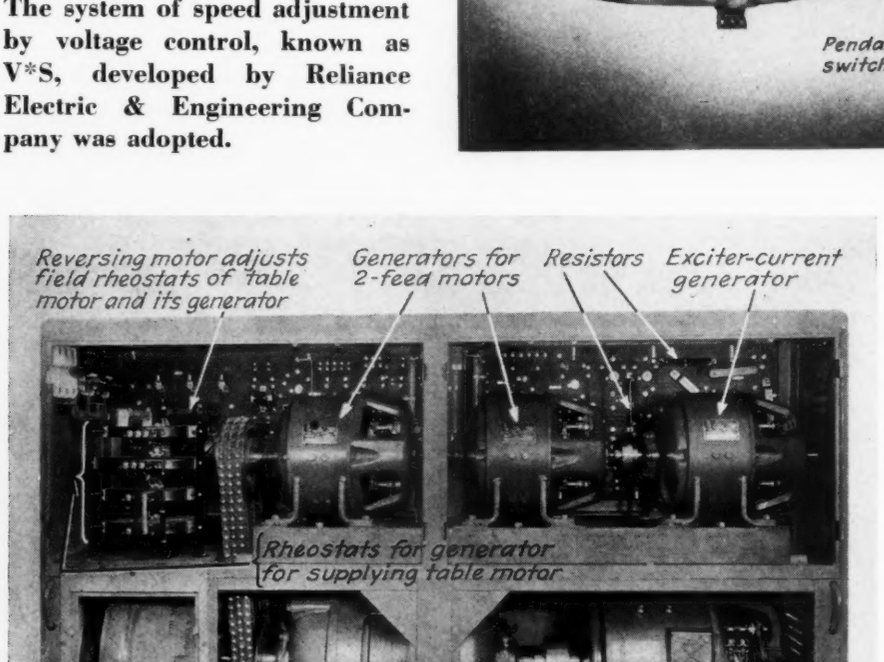


View looking forward of center panel assembled to fuselage. Fuselage is an all-wood semi-monocoque construction. The outer surfaces of the skin are each continuous sheets presenting unbroken smooth surfaces. The number of plies between the surface sheets increases toward the center of the fuselage to give increasing thickness in proportion to the total shear across the different sections of the structure, the shear being a maximum at the wings. For troop-carrying missions light, sturdy wall seats are provided which can be folded out of the way in order to make maximum use of all interior room when fuselage space is to be occupied by cargo.

TANK TURRETS MACHINED FASTER ON MILLS EQUIPPED WITH VARIABLE VOLTAGE SPEED CONTROL

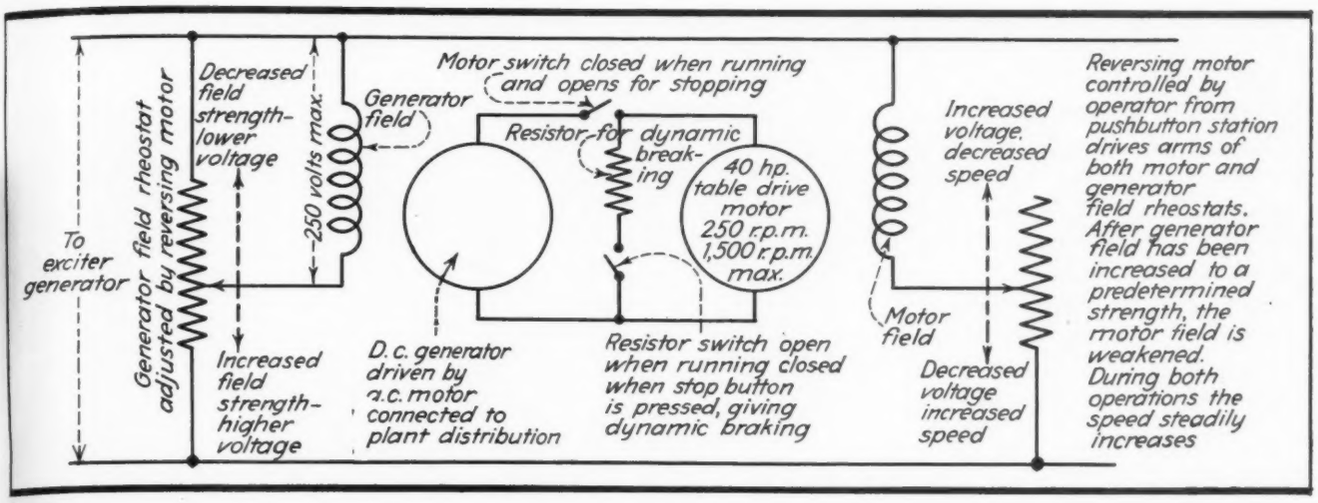
All-electric adjustable speed drives were applied to the line of boring mills designed by Consolidated Machine Tool Company and now being built by the Fisher Body Division of General Motors Corporation and others. To be used in several different plants for machining tank turrets, it was important that the drive selected be suitable to the various types of electric power available in the different plants, that the controls be so simple that they could readily be mastered by men without previous experience in handling this kind of equipment and that the control equipment be compact. Also, a drive with a wide range of speed control was essential. Earliest possible delivery was also an important consideration. The system of speed adjustment by voltage control, known as V*S, developed by Reliance Electric & Engineering Company was adopted.




Reversing motor adjusts field rheostats of table motor and its generator
Generators for 2-feed motors
Resistors
Exciter-current generator
Rheostats for generator for supplying table motor
Air filter
Cooling fan
60 hp. squirrel-cage a.c. motor, drives four generators and cooling fan
Generator for table motor

Control unit and control stations are arranged the same on each of the three sizes of boring mills, 72 in., 100 in. and 112 in. Table is driven through a fixed gear train—a helical gear and pinion and a spiral bevel pair. Feed drives have their individual 5 hp. motors, thus eliminating mechanical drive from table and complicated change gears. Coolant and lubricating pumps are also separately driven by a.c. motors.

Rear view of control unit with the door removed is shown to the left. The 60 hp. squirrel-cage motor drives all four generators and the cooling fan. Mounting the two feed-motor generators, exciter generator and rheostat above the main generator, driving motor and cooling fan, and connecting by V-belt drive, saves considerable floor space and gives better access to the resistors and connections.


To exciter generator
Generator field rheostat adjusted by reversing motor
Decreased field strength-lower voltage
250 volts max.
Generator field
Motor switch closed when running and opens for stopping
Resistor for dynamic breaking
40 hp. table drive motor 250 r.p.m. 1,500 r.p.m. max.
Increased field strength-higher voltage
D.c. generator driven by a.c. motor connected to plant distribution
Resistor switch open when running closed when stop button is pressed, giving dynamic braking
Increased voltage, decreased speed
Motor field
Decreased voltage increased speed
Reversing motor controlled by operator from pushbutton station drives arms of both motor and generator field rheostats. After generator field has been increased to a predetermined strength, the motor field is weakened. During both operations the speed steadily increases

Schematic circuit diagram explaining how speed of table drive motor is controlled over a range from 250 r.p.m. min. to 1,500 r.p.m. max., the corresponding table speeds being 1.75 and 10.5 r.p.m. Actually the minimum table speed attainable is 0.125 r.p.m., one revolution in eight minutes, and maximum is 14 r.p.m., without any changes in mill or electrical equipment. Table can be jogged as little as a few thousandths of an inch in either direction independently of its operating speed setting. The hook-up for feed motors is similar with the exception that the generator field rheostat is mounted in the control station.

For dynamic braking, when motor switch opens upon pressing "Stop" button, the resistor switch closes simultaneously. The motor then acts as a generator and pumps current through the resistor thus quickly stopping the motor. When running at maximum speed table is stopped in about one-half revolution. By means of an electrical interlock which includes a time-delay relay, feed motors stop before table stops, after any "Stop" button controlling the table motor is pressed.

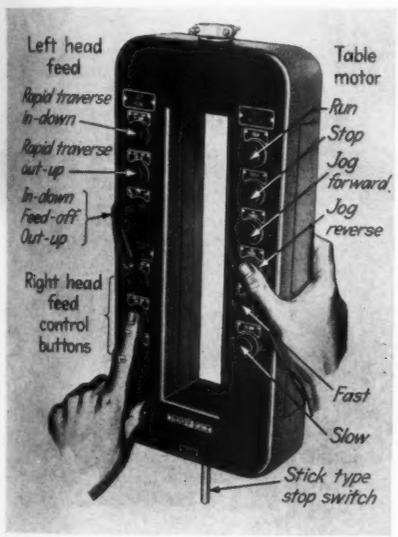
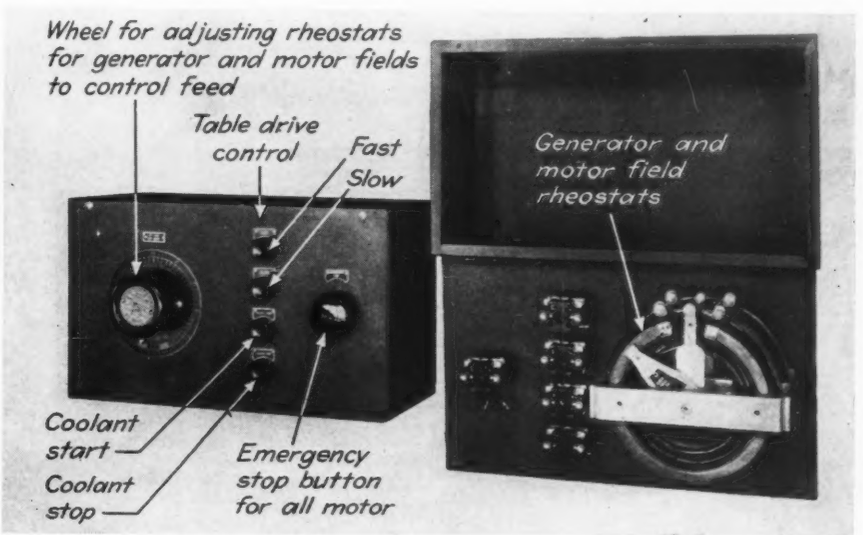


Table and feed motor operations can be controlled from the pendant switch. The "O" shape was selected because it makes it easy to grasp the pendant and operate buttons with either hand. The double row of buttons makes unit compact and convenient. For safety reasons, the additional "stick" type "Stop" switch was provided. When any table motor "Stop" switch is pressed, feed motor is also stopped, a time delay relay causing the feed motor to stop before the table motor stops. Restarting the table motor does not restart the feed motor. Dynamic braking provides quick stopping for both functions.


Wheel for adjusting rheostats for generator and motor fields to control feed
Table drive control
Fast
Slow
Generator and motor field rheostats
Coolant start
Coolant stop
Emergency stop button for all motor

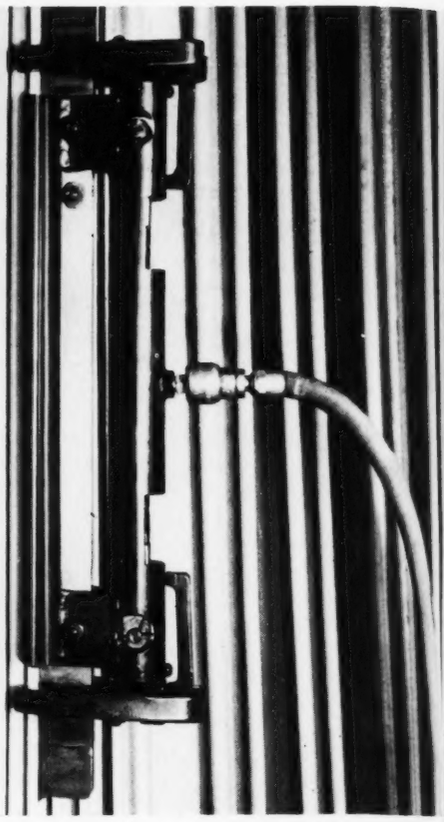
Speed control of the 5 hp. feed motors is from the feed drive control stations, one on each of the boring mill columns. Each of these stations also includes "Fast" and "Slow" buttons for the table drive, "Stop" and "Start" buttons for the coolant pump and a mushroom type emergency "Stop" button. Voltage control rheostats for feed-motor generators are mounted in the control station and adjusted manually instead of by reversing motor. With a combination of the electrical feed drive and two gear shifts, one of which provides for rapid traverse, the guaranteed minimum feed range is 0.0035 in. to 4.37 in. per min. and traverse speed is 50 in. per min. Actual maximum feed is 5½ in. per min. or between 0.4 to 0.5 in. per table revolution.

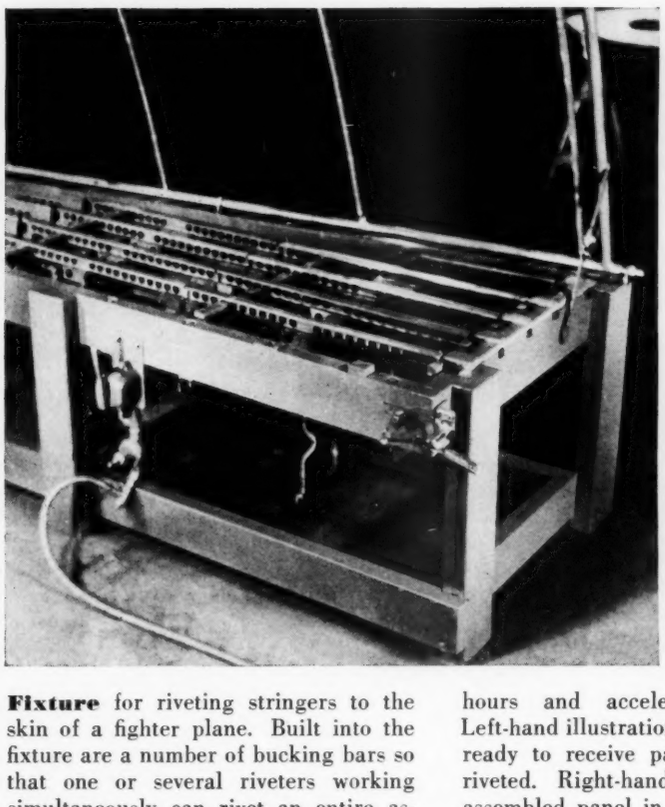
Limit switches prevent over-travel of feed or rapid traverse. Similarly, a limit switch is operated from the rapid traverse gear shift lever and makes the feed control inoperative at the same time that it energizes the rapid traverse control.

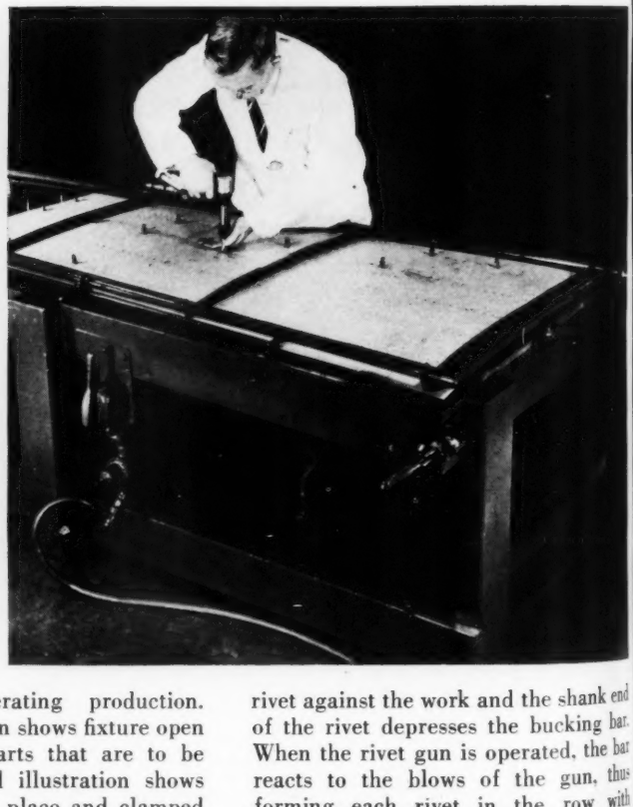
A pressure limit switch actuated by the pressure of the oil lubricating system insures that the mill cannot run unless the lubricating oil is under pressure. Oil pump motor must be started first and boring mill shuts down automatically if oil pressure is lost.

BUCKING BAR SIMPLIFIES AIRCRAFT RIVETING

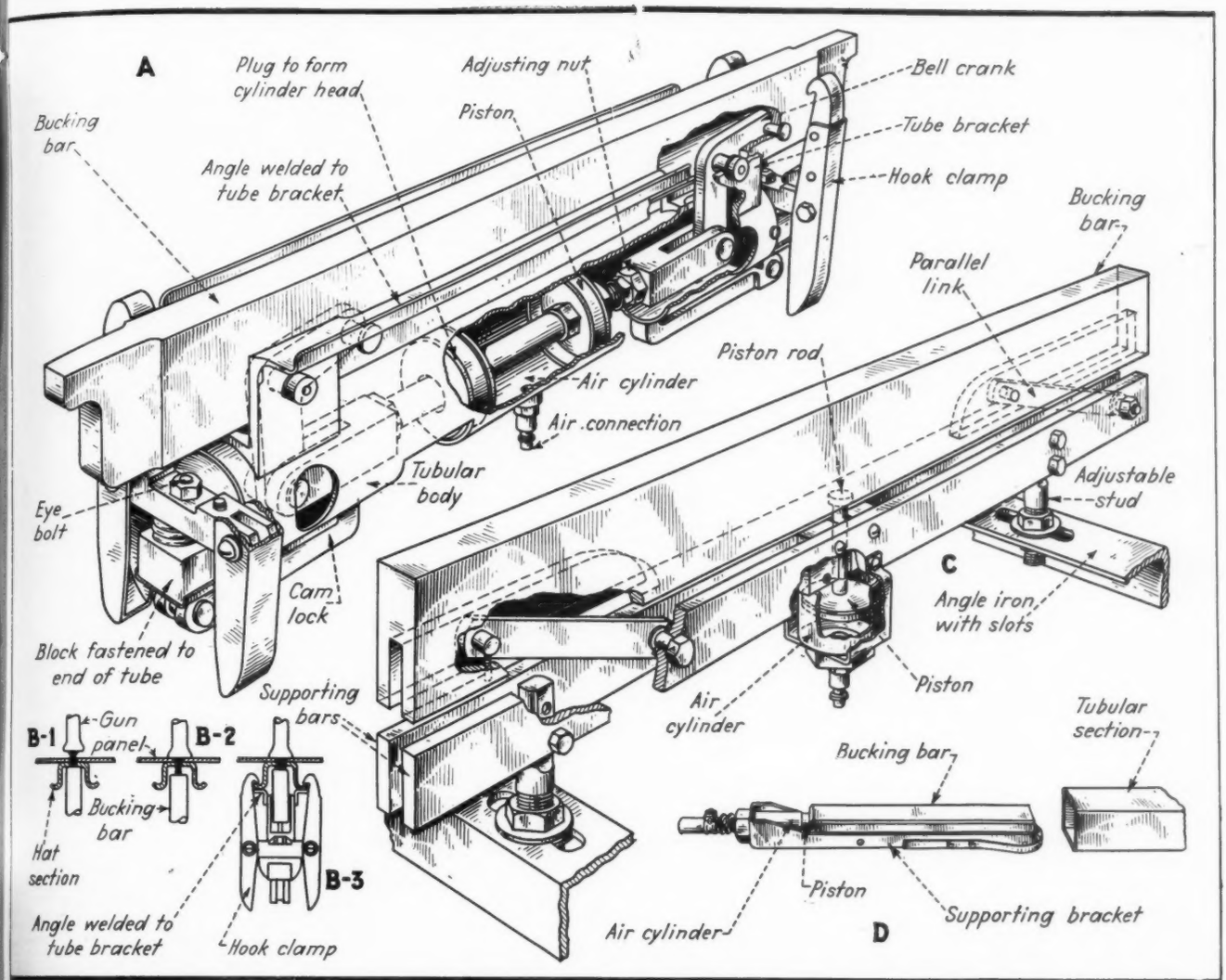
A practical answer to the Government's urgent request for increased production in war industries is the automatic bucking bar which was developed under the direction of A. H. Haberstump, by the product research division of the Murray Corporation of America. The bucking bar was designed with the objectives of promoting more efficient methods of assembly, speeding production, and eliminating unnecessary labor and inconvenience for the riveters. On aircraft assemblies riveting efficiency has been increased 52 percent over that obtained with conventional methods. Also the number of riveters that can work at one time on a single assembly has been increased from one to several. Air-operated, the automatic bucking bar replaces traditional "bucker" of riveting team.







Fixture for riveting stringers to the skin of a fighter plane. Built into the fixture are a number of bucking bars so that one or several riveters working simultaneously can rivet an entire assembly without removing it from the fixture, thus increasing productive man-hours and accelerating production. Left-hand illustration shows fixture open ready to receive parts that are to be riveted. Right-hand illustration shows assembled panel in place and clamped in fixture. After inserting rivet in hole, the riveting gun pushes the head of the rivet against the work and the shank end of the rivet depresses the bucking bar. When the rivet gun is operated, the bar reacts to the blows of the gun, thus forming each rivet in the row with square and uniformly shaped "buck-tails" of even height.



Each bucking bar is a long, rectangular shaped part connected by a parallel motion linkage to a small air cylinder. Several constructions have been employed. In the portable type shown at *A*, which has been designed for a particular stringer hat section, a tube forms the body of the structure and also provides a cylinder in which the piston operates. A plug is pressed some distance into the tube to form the closed end of the cylinder. To the ends of the tube, blocks are secured which guide eye-bolts that carry the bridge on which clamps are hinged. These hook clamps are secured to the edges of hat sections, which are to be riveted, by cam locks that pull on the spring-loaded eye-bolts. Angles welded to and parallel with the tube body are also squeezed against the faces of the hat sections by the action of the cam locks.

The arrangement of the linkage that constrains the face of the bucking bar to be parallel with center line of the tube and piston rod consists of two bell cranks, the respective arms of which are exactly equal. The bell cranks turn about pins mounted in brackets that are welded to the tube. These brackets also carry the angles which abut against the faces of the hat sections. Arms of the bell cranks, that extend into recesses in the back of the bucking bar, are connected to the bucking bar with through pins. Other arms are pin-connected to clevis fittings on the ends of the piston rod.

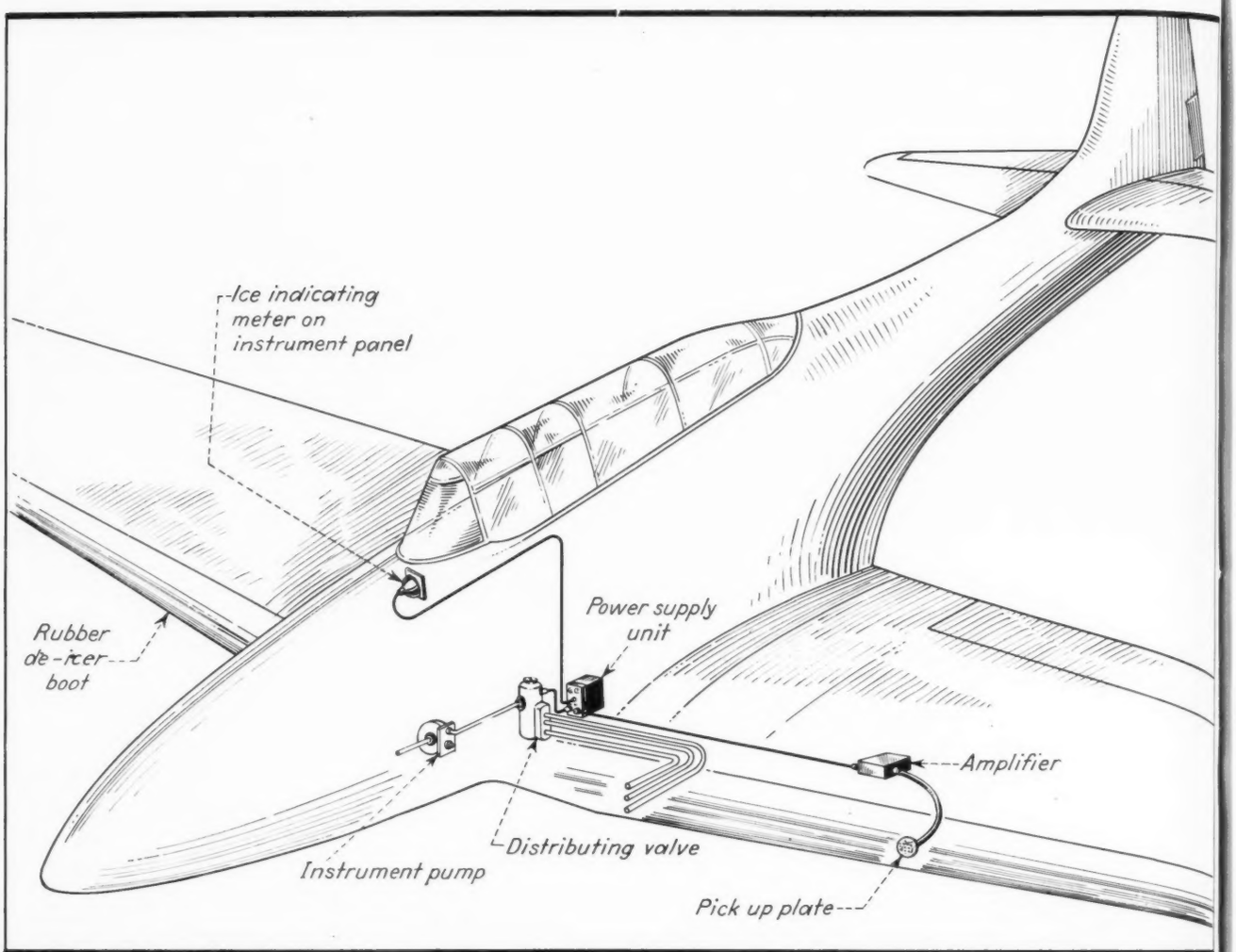
When using this tool, the riveter clamps the bucking bar into position against a hat section and places the rivet in the hole as shown in *B*-1. The rivet is then pushed down against the surface of the work, using the end of the riveting gun, thus depressing the bucking bar as shown in *B*-2. While the rivet is held in this position with the gun, the trigger is pulled and the bucktail is formed, as shown in *B*-3, by the bucking bar.

Riveting can be done at any position on the bar with uniform results because of the parallel motion construction which presents the entire weight of the bar for bucking irrespective of the position of the riveting operation.

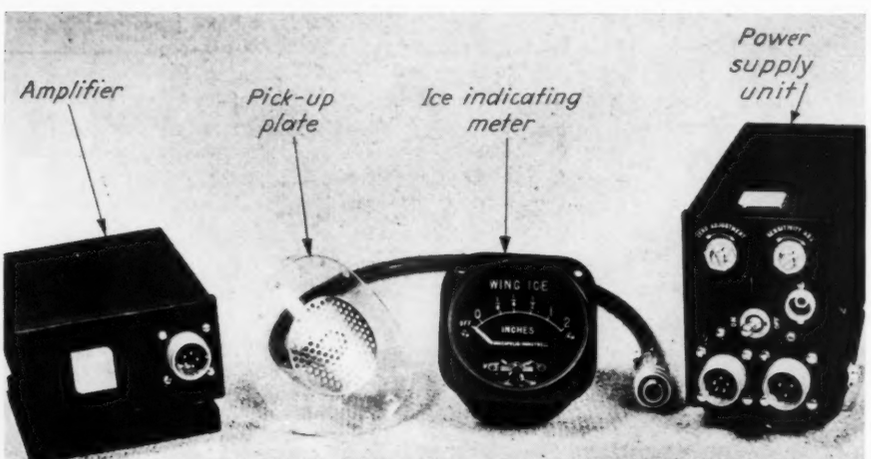
In the fixture type bucking bar, as show at *C*, as many bars as necessary are assembled in the fixture to back up the rows of rivets. Means for clamping the work to the bucking bars are provided in the fixture. *C* shows a typical bar mounted on two angle irons which are slotted to provide adjustment of the bar in alignment with the holes to be riveted. The bar is mounted on two studs which can be adjusted vertically. The parallel motion action is obtained by using links of equal length to connect the bucking bar to the two supporting bars. The air cylinder is carried by the two supporting bars, with the piston extending upward and bearing against the bucking bar. The several bars in the fixture are adjusted to take up any spring in the panel as riveting is done.

Bucking bar for riveting tubular sections, shown in *D*, consists of an air cylinder, piston and bucking bar attached to a supporting bracket on the end of a long pipe which can be pushed into the tube that is to be riveted. The piston bears against one end of the bucking bar. Bucking bar is hinged to the supporting bracket with two parallel links which supply the constraint for the parallel motion.

DE-ICERS CONTROLLED BY ELECTRONIC DEVICE

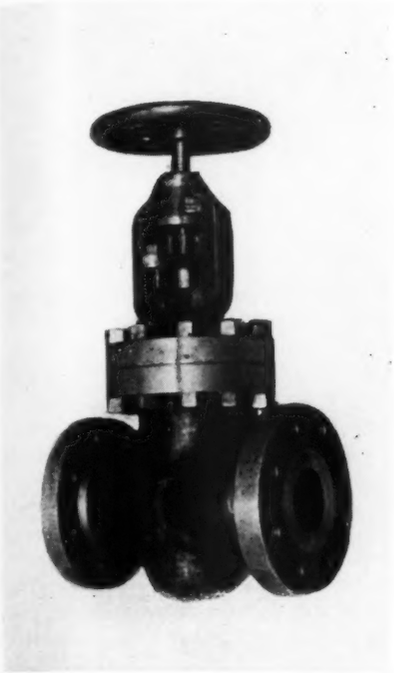


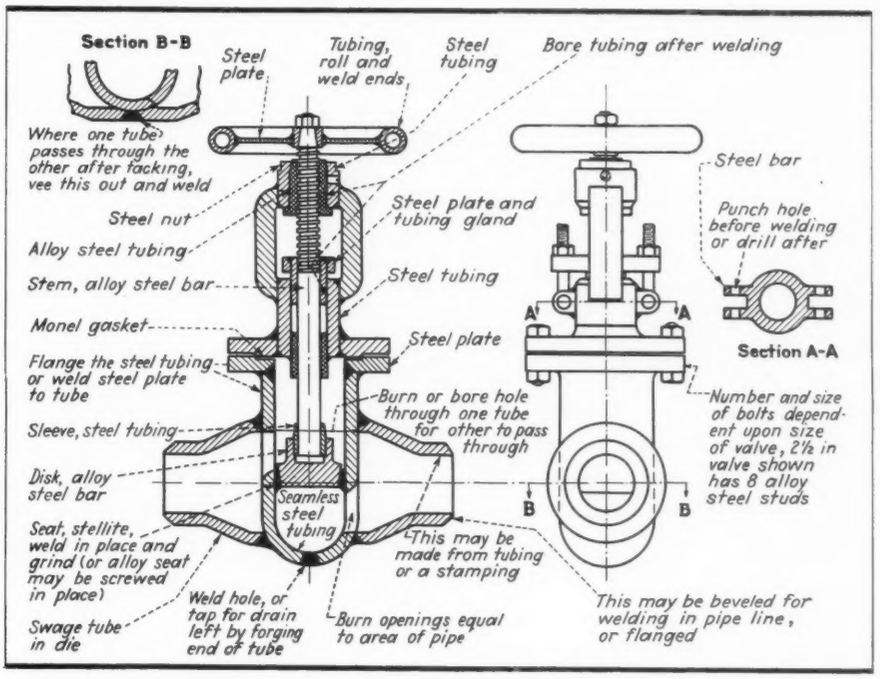
Thickness of ice formation and the rate of its accretion on the edges of aircraft wings is measured by the Electronic Ice Indicator developed by W. J. McGoldrick, vice-president in charge of aeronautical research, and Dr. Waldo Kliever, physicist, for Minneapolis-Honeywell Regulator Company. The instrument and its accessories also can be adjusted to turn on automatically the de-icers at the moment that they will be most effective. The pick-up plate or sensing element is an electrode set within a plastic disk about 3½ in. in dia. The pick-up plate is curved to fit the leading edge of a plane wing and is usually mounted underneath the de-icer boot.



When the ice indicator is operating an electronic field is set up between the electrode and the plane. As ice forms over the pick-up plate the character of the field is altered in direct proportion to the thickness of the accumulation. Connected to the sensing element is an amplifier, contained in a small aluminum, shock-mounted box. The amplifier multiplies the strength of the impulses coming from the electrode, then transmits the magnified impulses to a power supply unit which energizes the meter that indicates the thickness of the ice as it forms on the wings. When the skin of ice attains a predetermined thickness the power supply unit automatically switches on the de-icers.

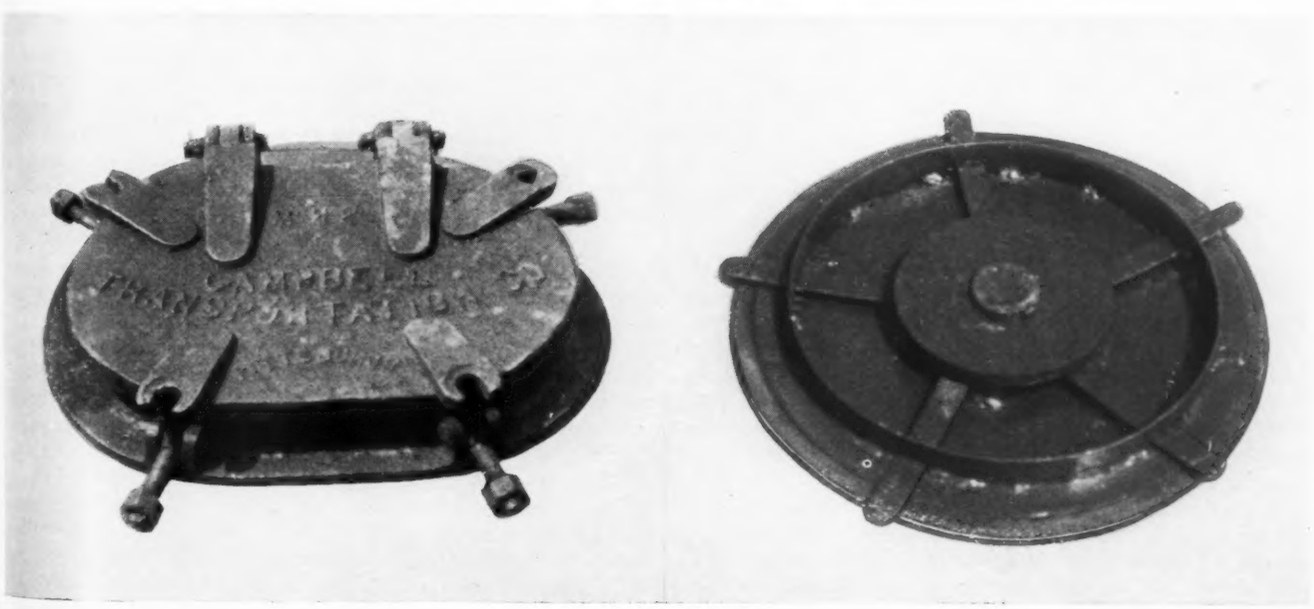
WELDED VALVE UTILIZES HIGH STRENGTH OF TUBING




Section B-B
Steel plate
Tubing, roll and weld ends
Steel tubing
Bore tubing after welding
Where one tube passes through the other after facking, vee this out and weld
Steel nut
Alloy steel tubing
Stem, alloy steel bar
Monel gasket
Flange the steel tubing or weld steel plate to tube
Sleeve, steel tubing
Disk, alloy steel bar
Seat, stellite, weld in place and grind (or alloy seat may be screwed in place)
Swage tube in die
Weld hole, or tap for drain left by forging end of tube
Seamless steel tubing
Burn openings equal to area of pipe
Steel plate and tubing gland
Steel tubing
Steel plate
Burn or bore hole through one tube for other to pass through
This may be made from tubing or a stamping
This may be beveled for welding in pipe line, or flanged
Steel bar
Punch hole before welding or drill after
Section A-A
Number and size of bolts dependent upon size of valve, 2½ in valve shown has 8 alloy steel studs
A
A'
B
B

Arc-welded of S.A.E. 1035 steel tubing, which has one-third higher tensile strength than cast steel, the 2½-in. high pressure globe valve shown above weighs only 100 lb. as compared with 200 lb. for a similar cast steel 2½-in. valve. Cost for the welded valve is 52 percent lower than cost of cast steel valve. Stress-relieved to 1,250 deg. F. before finishing, the welded valve body is almost equal in strength to a 6 percent Cr.-0.05 percent Mo. heat-treated steel casting. Valve stem, stem guide, disk and valve seat are all of stainless steel or Monel metal welded with Monel, stainless, Stellite, bronze, or mild steel electrodes depending upon the requirements of service conditions.

WELDED MANHOLE COVER COSTS $21.90 LESS



Redesigned manhole covers of welded construction saved $21,681 on one order for 45 large steel barges alone. Conventional covers, shown at left, were made of steel castings. Rim was welded or riveted to deck. Cover with rubber gasket is hinged to rim and battened down by lugs. New arc-welded cover, shown upside down at right, lies flush with the deck and is locked in place by 5 spring steel bars. Simple malleable iron locking hub is turned by a wrench from the top face of the cover. Welded cover is sealed by a large rubber gasket and two small fibre gaskets. A reinforcing doubling plate welded under deck forms a clamping ring and gasket surface.

Stress Concentration Factors And Their Effect on Design

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Department of Machine Design, Cooper Union

Stress concentration factors that are most useful and dependable in the computation of design stresses at weak points in many forms of design have been selected and correlated from the work of many investigators. The tabulation includes only directly applicable factors and omits data having doubtful bases or extremely limited application in engineering design.

MANY aircraft, automobile, pump and other machine parts have failed in normal service at stresses far below the calculated allowable nominal stresses as determined by laboratory endurance tests on smooth specimens. The typical fracture appears brittle and shows unmistakable evidence of the way it occurred. The story of fatigue failure has been appropriately described (Ref. 1) as a tale of notches, nicks, keyways, oil holes, screw threads, scratches, rough surfaces, quenching cracks, grinding cracks, sharp changes in section, thin outstanding fins, poor fillets, tool marks, inclusions in the metal, corrosion pits, and the like, that is, some localized nucleus from which failure started. Some of these cannot be avoided. When a screw thread or an oil hole is needed, it must be used, but there is no need to use the worst kind of a screw thread, the oil hole need not be rough nor its edges unrelieved, nor need the oil hole always be put in the worst location as far as fatigue is concerned.

The distribution of stress across an ordinary tensile test specimen is nominally uniform and is equal to the load divided by the cross-sectional area. If now a small transverse hole be drilled through the center of the specimen, the engineer might compute the nominal stress by dividing the load by the net cross-sectional area. However, the theory of elasticity, photoelastic measurements, or actual strain measurements will show that the stress is not uniformly distributed but varies across the section, and the maximum stress, which occurs at the surface of the hole, is several times the nominal stress. The ratio of this actual maximum stress to the nominal stress is called the stress concentration factor. Similarly, a small transverse hole in a beam subjected to pure bending will cause a high localized stress at the edge of the hole, which is greater than the nominal stress obtained by the flexure formula $\sigma = Mc/I$, where σ is the stress at the distance c from the neutral axis to the outer edge of the hole resulting from the bending moment, and I is the area moment of inertia of the net section. The stress concentration factor in this instance also is defined as the ratio of the maximum stress at the hole divided by the nominal stress at the hole.

Of course, it must be kept in mind that the stress concentration factors as obtained by the theory of elasticity hold only when the maximum stress is within the elastic limit. Any plastic yielding that occurs as a result of overstressing greatly relieves stress concentrations, even in relatively brittle materials, causing them to have far less influence than might be expected from a consideration of the elastic stresses only. The practical significance of stress concentration, therefore, depends on circumstances. Stress concentrations are usually of little or no importance for ductile materials subjected to static loading but are of prime importance for brittle materials subjected to static loads and for either brittle or ductile materials subjected to repeated loads, that is, fatigue loading.

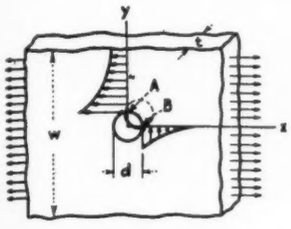
Even the most highly localized stress concentrations, such as those produced by small surface scratches or tool marks, may seriously lower the nominal endurance limit but susceptibility to stress concentrations, or "notch sensitivity" as it is sometimes called, varies widely among materials. This effective stress concentration factor in fatigue may be defined as the ratio of the endurance limit of a plain specimen to that of a specimen containing the stress concentration.

There is evidence that the stress concentration factor in fatigue increases with size of specimen and fineness of grain and that it approaches the theoretical stress concentration factors based on the theory of elasticity, photoelastic measurements, or strain measurements. Another important fact having practical implications is that the deleterious effect of an unavoidable stress raiser can sometimes be mitigated by putting in additional discontinuities of the proper kind. Thus a single V-groove reduces the strength of a part more than does a continuous screw thread of identical form. Also a single isolated notch or hole has a worse effect than do a number of similar stress raisers placed close together.

A table of 31 theoretical stress-concentration factors is given in the following pages. A number of additional cases that have been described in the literature have not been overlooked but do not appear in this compilation for various reasons. Thus the results of Thomas (Ref. 19) on the effect of notches and workshop finishes have been quoted frequently, but since his results were obtained on small fatigue specimens they are of extremely doubtful value and err on the unsafe side. There have also been a number of papers on the stress-concentration effects of cavities and inclusions but they only emphasize the importance of sound, clean homogenous metal.

The theoretical stress-concentration factors which follow are the ratios of the actual maximum stress $\sigma_{max.}$ to the nominal stress $\sigma_{nom.}$, that is, $k = \sigma_{max.}/\sigma_{nom.}$. The user must be careful to note the definition of nominal stress given for each case. Some are defined on the basis of net area while others, for convenience, are based on original area without the stress raiser. In some cases the effect of stress concentrations are expressed in terms of only one of the nominal stresses resulting from a given type of loading. Tensile stresses are given a positive sign while compressive stresses are given a negative sign in the following tabulation of factors.

CASE I — FLAT PLATE. SMALL TRANSVERSE HOLE IN SIMPLE TENSION OR COMPRESSION. (Ref. 3)

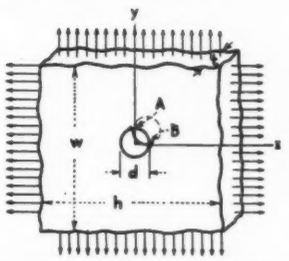


σ_x = nominal or average stress across net section $(w-d)t$
$\sigma_A = 3\,\sigma_x$
$\sigma_B = -\sigma_x$

Thus stress concentration factor k at point A is $\sigma_A/\sigma_x = k = 3$ and at B is $\sigma_B/\sigma_x = k = -1$.

These values hold only when w is large compared with d ($w > 20d$). See Case V. Stress distribution along x and y axes is indicated.

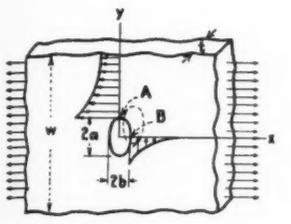
CASE II — FLAT PLATE. SMALL TRANSVERSE HOLE IN PLANE STRESS



σ_x = average stress across net section $(w-d)t$
σ_y = average stress across net section $(h-d)t$
$\sigma_A = (3 - \sigma_y/\sigma_x)\sigma_x$
$\sigma_B = (3 - \sigma_x/\sigma_y)\sigma_y$

These values are obtained from Case I by the principle of superposition and hold only when w and h are large compared with d ($w > 20d$ and $h > 20d$).

CASE III — FLAT PLATE. SMALL ELLIPTICAL TRANSVERSE HOLE IN SIMPLE TENSION OR COMPRESSION. (Ref. 3)

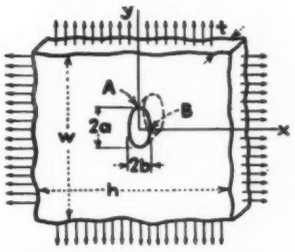


σ_x = average stress across net section $(w-2a)t$
$\sigma_A = (1+2a/b)\,\sigma_x$
$\sigma_B = -\sigma_x$

Stress concentration factor is largest when the major axis of the elliptical hole is perpendicular to the direction of the stress σ_x.

These values hold when w is large compared with $2a$ ($w > 40a$). For smaller ratios the stress concentration factor is somewhat reduced.

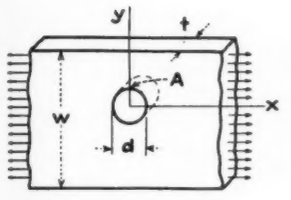
CASE IV — FLAT PLATE. SMALL ELLIPTICAL TRANSVERSE HOLE IN PLANE STRESS

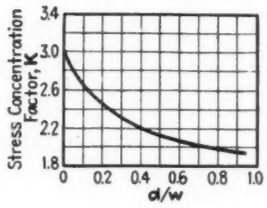


σ_x = average stress across net section $(w-2a)t$
σ_y = average stress across net section $(w-2b)t$
$\sigma_A = (1+2a/b-\sigma_y/\sigma_x)\sigma_x$.
$\sigma_B = (1+2b/a-\sigma_x/\sigma_y)\sigma_y$

These values are obtained from Case III by the principle of superposition and hold only when w and h are large compared with $2a$ and $2b$ ($w > 40a$ and $h > 40b$).

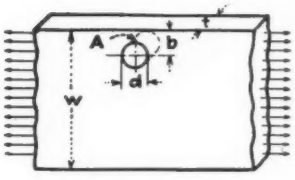
CASE V — FLAT PLATE. LARGE TRANSVERSE HOLE IN SIMPLE TENSION OR COMPRESSION. (Ref. 4, 5, 6)

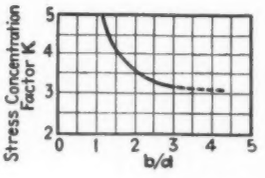




$\sigma_A = k\sigma_{nom.}$
$\sigma_{nom.}$ = average stress across net section $(w-d)t$

CASE VI — FLAT PLATE. SMALL TRANSVERSE HOLE NEAR EDGE OF PLATE IN SIMPLE TENSION OR COMPRESSION. (Ref. 7)

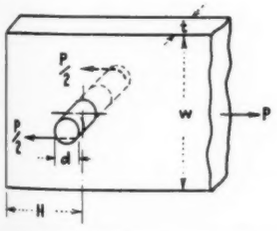


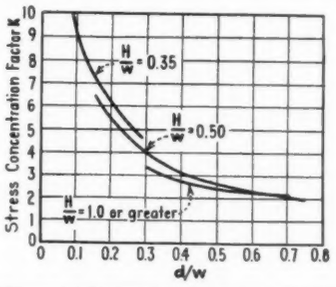


$\sigma_A = k\sigma_{nom.}$
$\sigma_{nom.}$ = average stress across net section $(w-d)t$

These values for the stress-concentration factor at point A hold only when w is large compared with d ($w > 20d$). For smaller ratios of w to d, the stress-concentration factors will be reduced somewhat.

CASE VII — FLAT PLATE. LOADED THROUGH PIN IN A CENTRAL CIRCULAR HOLE. (Ref. 8)

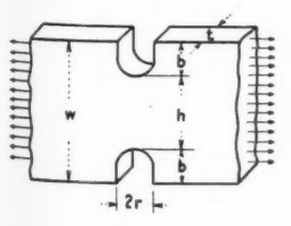


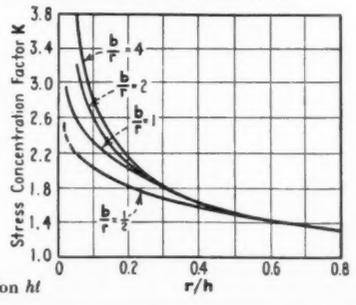


$\sigma_{nom.}$ = average stress across net section
$= P/(w-d)t$
$\sigma_{max.}$ = max. stress $= k\sigma_{nom.}$

These stress concentration factors are for neat fitting pins. If there is a small clearance between pin and hole the stress concentrations are considerably increased, as much as 50 percent depending on the clearance. A little clearance is more detrimental than a moderate press fit. If the load is equally distributed between two symmetrically situated pins, the stress concentration factors may be decreased as much as 20 percent.

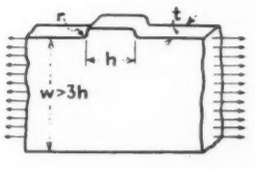
CASE VIII — FLAT PLATE. DEEP AND SHALLOW CIRCULAR NOTCHES IN SIMPLE TENSION OR COMPRESSION. (Ref. 4, 6, 9)

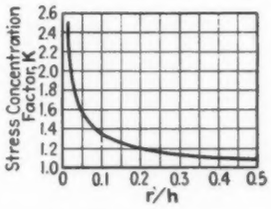




$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.}$ = average stress across net section ht

CASE IX — FLAT PLATE. PROTRUSION IN SIMPLE TENSION OR COMPRESSION. (Ref. 10)

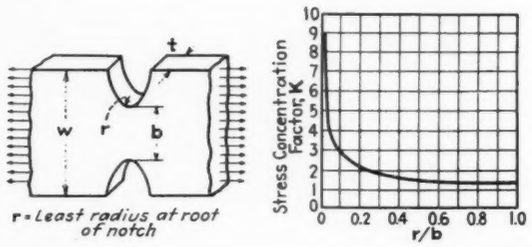




$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.}$ = average stress across net section wt

The above stress concentration factors show why welds should be ground flat in important stressed members.

CASE X — FLAT PLATE. HYPERBOLIC NOTCHES IN SIMPLE TENSION OR COMPRESSION. (Ref. 10, 11)

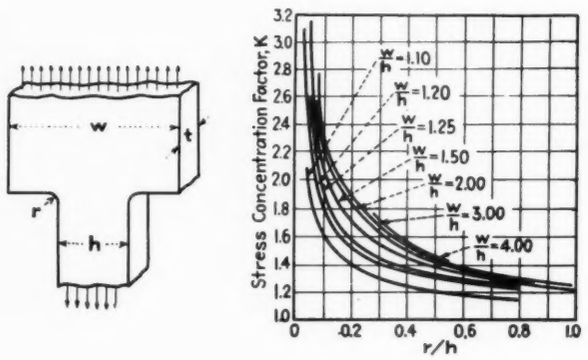


$\sigma_{max.} = k\sigma_{nom.}$

$\sigma_{nom.}$ = average stress across net section bt

These values hold theoretically for $w = \infty$, though it is probably sufficiently close when depth of notch is at least four times the least radius of curvature r. (Compare with Case VIII). The values of k given in chart may be used as a close approximation for any type of V-notch with a small fillet of radius r at the root of the notch.

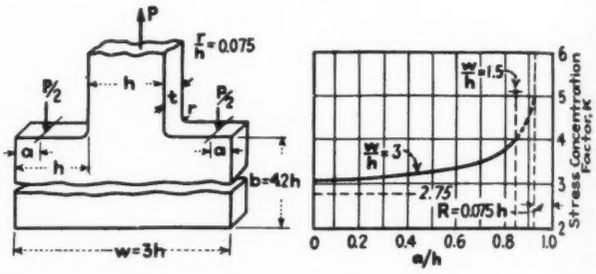
CASE XI — FLAT PLATE. FILLETS IN SIMPLE TENSION OR COMPRESSION. (Ref. 4, 9)



$\sigma_{max.} = k\sigma_{nom.}$

$\sigma_{nom.}$ = average stress across net section ht

CASE XII — FLAT PLATE. T-HEAD SUPPORTED ALONG THE FLANGES WITH CONCENTRATED LOADS AND SUBJECTED TO AN AXIAL PULL. (Ref. 12)



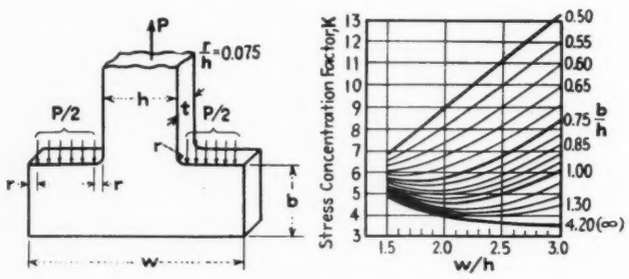
$\sigma_{max.} = k\sigma_{nom.}$

$\sigma_{nom.} = P/ht$

The values given are for a constant fillet ratio $r/h = 0.075$ and show the increased stress concentration effect as the load moves in toward the fillets. The effect of bending of the flanges was minimized since $b = 4.2h$ and is therefore quite stiff. (See Case XIII).

For the value of $a/h = 0.84$ and $w/h = 3$, $k = 4.05$; when $a/h = 0.84$ and $w/h = 1.5$, it is found that $k = 5.10$. Thus the effect of decreasing the ratio w/h is opposite to that of Case XI, also see Case XIII for $b/h = 4.2$. The $k = 2.75$ is for the case when $w/h = 3$ and $r/h = 0.075$ in flat plate with fillets subjected to simple axial stress (Case XI).

CASE XIII — FLAT PLATE. T-HEAD SUPPORTED ALONG THE FLANGE WITH UNIFORMLY DISTRIBUTED LOAD AND SUBJECTED TO AN AXIAL PULL. (Ref. 12)

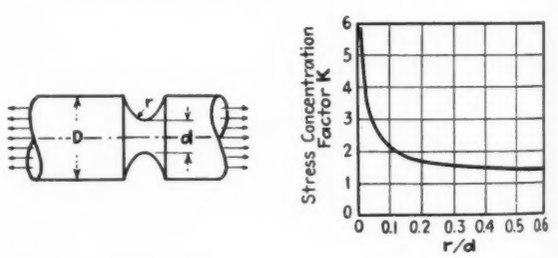


$\sigma_{max.} = k\sigma_{nom.}$

$\sigma_{nom.} = P/ht$

These results show the effect of bending of the flanges as depth b is decreased. The distributed loads eliminate one variable — the effect of location of load with respect to the fillet — and justifies the statement in Case XII.

CASE XIV — CIRCULAR SHAFT. HYPERBOLIC GROOVE IN SIMPLE TENSION OR COMPRESSION. (Ref. 10)



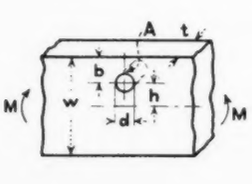
r = least radius of curvature at root of notch

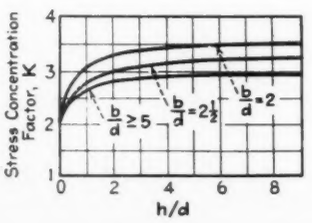
$\sigma_{max} = k\sigma_{nom.}$

σ_{nom} = average stress across section of diameter d

These values hold theoretically for $D = \infty$, though it is probably sufficiently close when depth of groove is at least four times the radius of curvature r. The values given in chart may be used as a close approximation for any type of V-groove with a small fillet of radius r at the root.

CASE XV — FLAT PLATE. SMALL TRANSVERSE HOLE IN PURE BENDING IN PLANE OF PLATE.



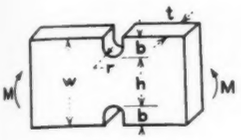


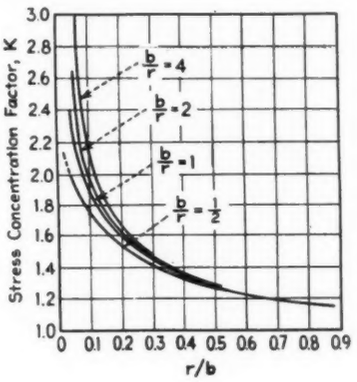
These stress-concentration factors are for the point A at the edge of the hole and not at the point of maximum nominal bending stress which occurs at the outside fibres. They were derived on the assumption that the ratio $b/d \geqq 2$ and the ratio $w/d \geqq 10$. For these limiting values the error is probably not over 10 percent. The stress-concentration factor probably increases with a decrease in the ratio b/d and decreases with a decrease in the ratio w/d.

The stress at point A is

$$\sigma_A = k\frac{6M\ (2h+d)}{(w-d)^2 t}$$

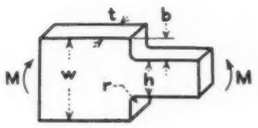
CASE XVI – FLAT PLATE. DEEP AND SHALLOW CIRCULAR NOTCHES IN PURE BENDING IN PLANE OF PLATE. (Ref. 4, 6, 9)

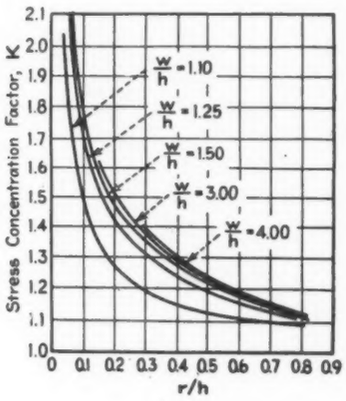




$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.} = Mc/I = 6M/th^2$ lb. per sq. in.
c = distance from neutral axis = $h/2$ in.
I = moment of inertia of net section
$= th^3/12$ in.^{4}
M = bending moment of section of depth h in in. lb.

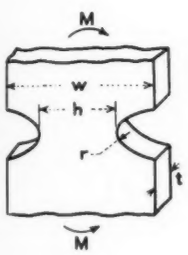
CASE XVII – FLAT PLATE. FILLETS IN PURE BENDING IN PLANE OF PLATE. (Ref. 4, 9)

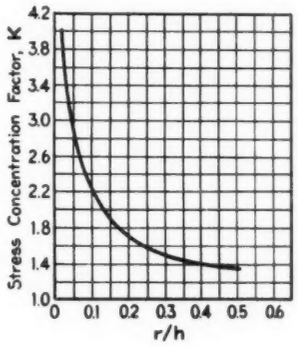




$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom} = 6M/th^2$ lb. per sq. in.
r = radius of fillet

CASE XVIII – FLAT PLATE. HYPERBOLIC NOTCHES IN PURE BENDING IN PLANE OF PLATE. (Ref. 10)

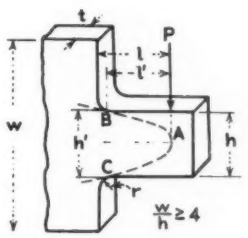


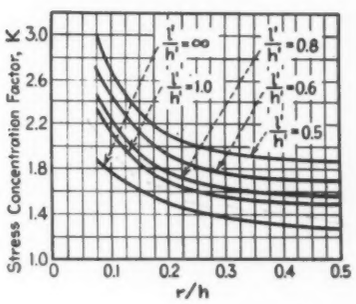


$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.} = 6M/th^2$
r = least radius of curvature at root of notch

These values hold theoretically for $w = \infty$, though it is probably sufficiently close when depth of notch is at least four times the least radius of curvature r. Compare with Case XVI. The values of k may be used as an approximation for any type of V-notch with a small fillet of radius r at the root of the notch.

CASE XIX – FLAT PLATE. FILLETS IN BENDING DUE TO A CONCENTRATED LOAD IN THE PLANE OF THE PLATE.

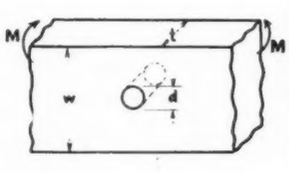


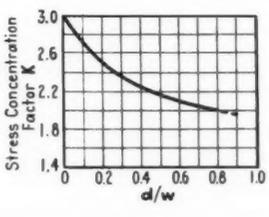


The assumed weakest section is located between the two points of tangency of the beam profile with a parabola ABC inscribed in the outline with the apex at the intersection of the action line of the load and the center line of the beam. The bending moment at this point being Pl' and the depth of section h'. The stress concentration factors given in the curves are for the section BC due to bending moment Pl'.

As the load P moves outward along the beam, i.e. $l' \rightarrow \infty$, the stress concentration factors should approach the values for pure bending as given in Case XVII for $w/h = 4$.

CASE XX – FLAT PLATE. HOLE IN THICK PLATE IN TRANSVERSE BENDING. (Ref. 6, 12)

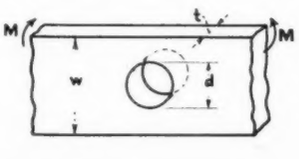


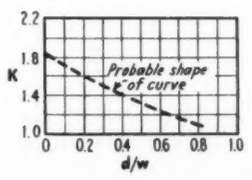


$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.} = 6M/(w-d)t^2$

Holds when hole is small in diameter compared with the thickness of the plate, say less than one-third. Based on the reasonable assumption that the stress-concentration factor is the same as when the plate is under tension.

CASE XXI – FLAT PLATE HOLE IN THIN PLATE IN TRANSVERSE BENDING. (Ref. 14)

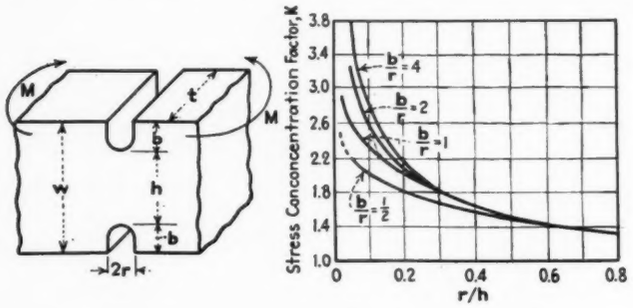




$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.} = 6M/(w-d)t^2$

Holds when the hole is relatively large in diameter compared with the thickness of the plate, say greater than three. For cases where the hole is of the same order of magnitude, it will be a matter of judgement as to the value that should be used.

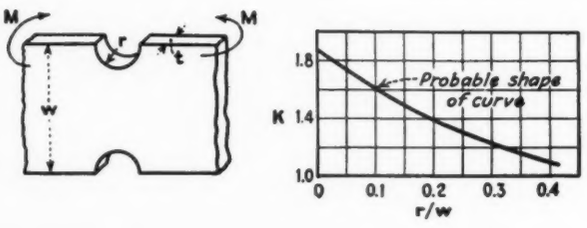
CASE XXII — FLAT PLATE. DEEP AND SHALLOW CIRCULAR NOTCHES IN THICK PLATE IN TRANSVERSE BENDING



$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.} = 6M/ht^2$

When the diameter of the notch is small compared with the thickness of the plate, say less than one-third, it is reasonable to suppose that the stress-concentration factors are about the same as in a similar plate in tension (Case VIII).

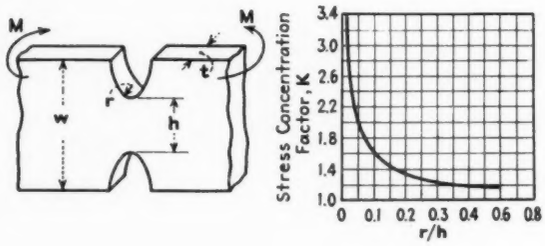
CASE XXIII — FLAT PLATE. SEMI-CIRCULAR NOTCHES IN THIN PLATE IN TRANSVERSE BENDING. (Ref. 14)



$\sigma_{max.} = \sigma_{nom.}$
$\sigma_{nom.} = 6M/(w-2r)t^2$

When the diameter of the semi-circular notch is greater than three times the thickness ($2r/h > 3$) the stress-concentration factors are considerably reduced, compare with Case XXII. When diameter of notch is of the same order of magnitude as the thickness, it will be a matter of judgement as to the value which should be used.

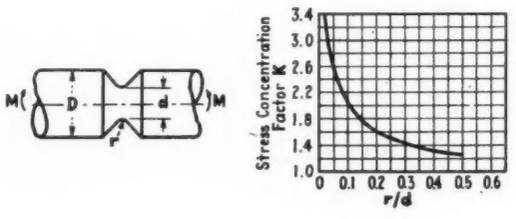
CASE XXIV — FLAT PLATE. HYPERBOLIC NOTCHES IN TRANSVERSE BENDING. (Ref. 10, 11, 15)



r = least radius of curvature at root of notch
$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.} = 6M/ht^2$

These values hold for $w = \infty$, though it is probably sufficiently close when depth of notch is at least four times the least radius of curvature r. (Compare with Case XXII). The values of k given in the chart may be used as a close approximation for any type of V-notch with a small fillet of radius r at the root of the notch.

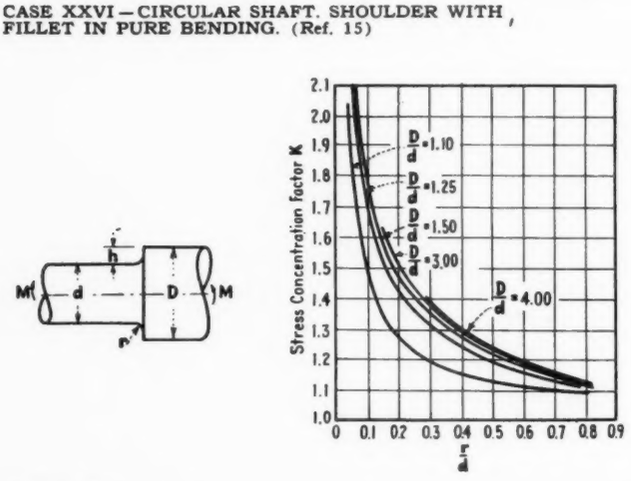
CASE XXV — CIRCULAR SHAFT. HYPERBOLIC GROOVE IN BENDING (Ref. 10, 15)



$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.} = 32M/\pi d^3$

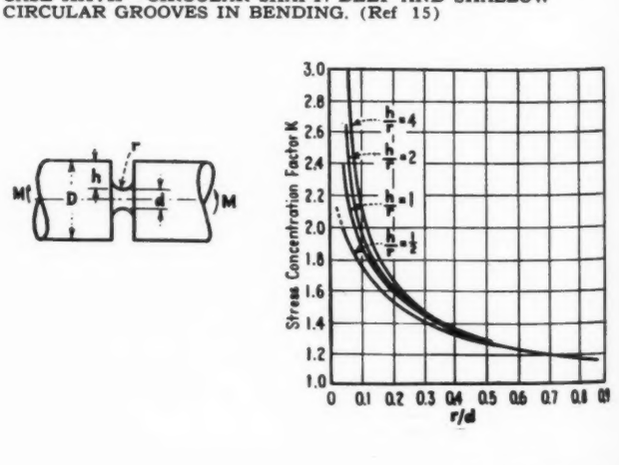
While these values of stress-concentration factors were derived for a bar of infinite diameter D, they may be used with fair accuracy on bars of finite diameter D and for any type of V-notch with a small fillet of radius r at the root when the depth of the groove is several times the root fillet radius.

CASE XXVI — CIRCULAR SHAFT. SHOULDER WITH FILLET IN PURE BENDING. (Ref. 15)



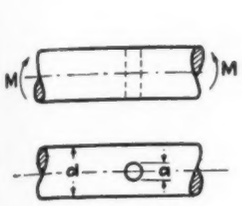
$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.} = 32M/\pi d^3$

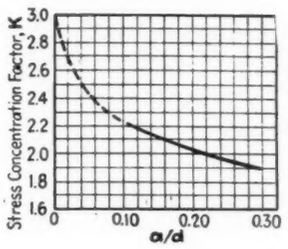
CASE XXVII — CIRCULAR SHAFT. DEEP AND SHALLOW CIRCULAR GROOVES IN BENDING. (Ref 15)



$\sigma_{max.} = k\sigma_{nom.}$
$\sigma_{nom.} = 32M/\pi d^3$

CASE XXVIII – CIRCULAR SHAFT. TRANSVERSE HOLE IN BENDING. (Ref. 15)

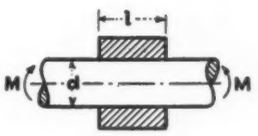


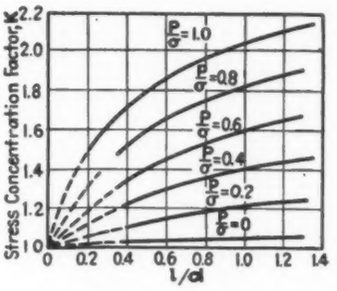


$\sigma_{max.} = k\sigma_{nom.}$

$\sigma_{nom.} = \dfrac{96M}{d^3(3\pi - 16a/d)}$

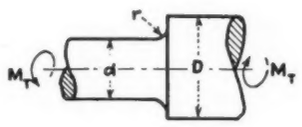
CASE XXIX – CIRCULAR SHAFT. PLAIN PRESS FIT IN BENDING. (Ref. 16, 17)

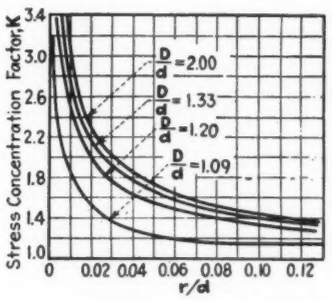




p = nominal press fit pressure in lb. per sq. in.
σ = nominal bending stress
$\sigma_{max.} = k\sigma$

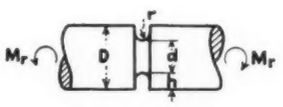
CASE XXX – CIRCULAR SHAFT. SHOULDER WITH FILLET IN TORSION. (Ref. 18)

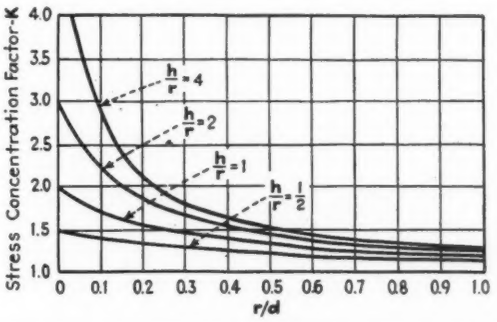




Maximum shear stress
$\tau_{max.} = k\,\dfrac{16M_T}{\pi d^3}$
M_T = applied torque, in.-lb.

CASE XXXI – CIRCULAR SHAFT. DEEP AND SHALLOW CIRCULAR GROOVE IN TORSION. (Ref. 18)





Maximum shear stress
$\tau_{max.} = k\,\dfrac{16M_T}{\pi d^3}$
M_T = applied torque, in.-lb.

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(16) Peterson, R. E., and Wahl, A. M., "Fatigue of Shafts at Fitted Members, with a Related Photoelastic Analysis." *Journal of Applied Mechanics*, March 1935.

(17) Discussion of Reference 16, *Journal of Applied Mechanics*, June 1935.

(18) Jacobsen, L. S., "Torsional Stresses in Shafts Having Grooves or Fillets." *Trans. A.S.M.E., Journal of Applied Mechanics*, 1935.

Tygon — A New Synthetic Corrosion-Resistant Material

Need of the process industries for a material with the corrosion-resistant properties of chemical stoneware and the desirable characteristics of rubber led to the development of a synthetic which ranges from liquid to bone-hardness in form.

RAPID GROWTH of the process industries has lead to a wide demand for a material with the corrosion-resistant properties of chemical stoneware and the desirable physical characteristics of rubber. Research by the U. S. Stoneware Company resulted in a series of synthetics that consist of modified halide polymers, new condensation resins and diene derivatives compounded to various formulas to produce materials with a wide range of physical characteristics.

Tygon, as the product of this research is called, ranges all the way from a liquid to a bone-hard solid form. It can be molded, cast or extruded; made into rigid, semi-rigid or flexible sheets or tubes; placed in solution with solvents for use as a coating or for pressure impregnation of porous materials. Solutions can be painted on surfaces to produce a flexible protective film that can be peeled off readily. It may be clear, translucent or opaque and can be colored by the addition of colorants. Surface finishes may vary from smooth to suede or crepe.

By means of an exclusive U. S. Stoneware process Tygon sheets may be bonded to metal, wood and concrete. No curing or vulcanizing is required in this process so there is no limit to the size of equipment that can be lined. The bond is said to be as nearly perfect as is possible to obtain.

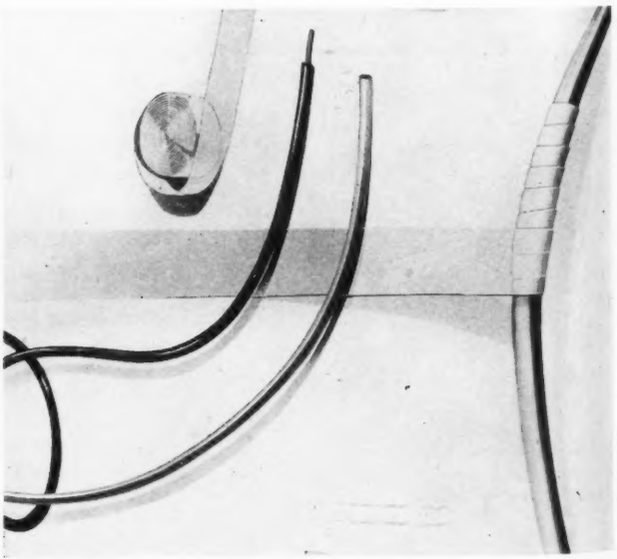
FORMULATIONS. At the present time, Tygon T is the principal formulation available. Tygon F, made entirely of agricultural waste, is one of the newest products. There are thermoplastic Tygons which have a top operating temperature of 175 deg. F., though some of the newer formulations have thermosetting characteristics which it is understood would permit operations at much higher temperatures.

APPLICATIONS. Although Tygon was originally developed as a material with the corrosion-resistance of chemical stoneware and the desirable physical characteristics of rubber, its use has been widely extended. It has turned out to be an extremely versatile construction material. Some applications, besides linings and coatings, include valve diaphragms, gaskets, insulations, tubing and impregnation.

CORROSION RESISTANCE. Chemical resistivity is indicated by the accompanying table. Oils and water have very little effect. No reaction was shown after 720 hr. of continuous exposure to a salt water spray. Air and sunlight have no oxidizing affect, indicating the extreme chemical stability of the material. Out of the Tygon series formulations are available which will resist practically any corrosive substance. This includes all inorganic acids except fuming nitric, all inorganic salts, all organic acids except glacial acetic, alkali solutions and most of the hydrocarbons and solvents, including the new aromatic high-octane fuels for aviation uses.

GENERAL PHYSICAL CHARACTERISTICS. Basic corrosion-resistant qualities are retained through a wide range of physical forms. Hard compounds can be turned, drilled and sawed and

Sheets are rigid, semi-rigid or flexible in thicknesses from 0.005 to 0.250 in. with crepe, suede, semi-matté or smooth finish



Tygon insulation and insulating tape resist oils, gasoline and water, are non-combustible and are not subject to oxidation

Properties* of Tygon T

	Unfilled	Filled	Rigid	Plasticized †
PHYSICAL				
Specific gravity, g. per cc	1.33–1.36	1.34–2.45	1.33–1.36	1.26
Specific volume, cu. in. per lb	20.7–20.3	20.6–10.5	20.7–20.3	.....
Refractive index, No. 20, deg. C	1.54	.....	1.53	.....
Flammability	Does not support combustion	Does not support combustion	Does not support combustion	Slow burning (2)
Specific heat, cal. per deg. C. per g	0.24	(1)	0.24	.....
Thermal conductivity, cal. per sq. cm. per cm. per sec. per deg. C	0.00039	(1)	0.00039	.....
Linear coefficient of thermal expansion, per deg. C	0.00007	(1)	0.00007	.....
MECHANICAL				
Modulus of elasticity, lb. per sq. in	35,000–40,000	35,000–80,000	35,000–40,000	.....
Modulus of rupture, lb. per sq. in	10,000–14,000	8,000–12,000	10,000–14,000	.....
Tensile strength, lb. per sq. in	8,000–10,000	6,000–12,000	8,000–10,000	2,800
Elongation, percent at break point at 25 deg. C	.....	.....	.....	325
Brinell hardness, 550 lb. at 3 min	12–15	15–25	12–15	.....
Hardness, Shore A	.....	.....	.....	80
Impact strength, izod, ft. lb	0.2–0.6	0.1–0.7	0.2–0.6	.....
Softening temperature, deg. C	60–65	65–75	60–75	(2)
Compressive strength, lb. per sq. in	10,000–12,000	.....	10,000–12,000	.....
Flexural strength, lb. per sq. in	12,000–14,000	.....	12,000–14,000	.....
Tendency to cold flow	Slight	Very slight	Slight	.....
Machining qualities	Very good	(1)	Very good	.....
With organic fillers	.....	Excellent	.....	.....
With mineral fillers	.....	Poor	.....	.....
Forming qualities by:				
Swaging	Very good	.....	Very good	.....
Blowing	Fair	.....	Fair	.....
Spinning	Fair	.....	Fair	.....
Shearing	Excellent	Fair	Excellent	.....
Abrasion resistance	Good	Good	Good	Good
Fatigue resistance	.....	.....	.....	1,000,000 flexes
ELECTRICAL				
Dielectric constant at radio frequency	4.0	(1)	4.0	(3)
Electrical resistivity at 30 deg. C., ohms per $cm.^3$	less than 10^{14}	10^{11}	10^{14}	.....
Break down voltage at 60 cycles, volts per mill	675	(1)	675	.....
Power factor at 1,000 cycles	0.014	0.02–0.15	0.014	.....
Power factor at radio frequency	0.018	0.02–0.06	0.018	.....
PHYSICO-CHEMICAL				
Effect of aging, room temperature	Unaffected	Unaffected	Unaffected	Slight stiffening
Effect of sunlight	Darkens on prolonged exposure	Darkens on prolonged exposure	Darkens on prolonged exposure	Slight darkening
Effect of ultra-violet light	Darkens on prolonged exposure	Darkens on prolonged exposure	Darkens on prolonged exposure	Slight darkening
Effect of hot water	Softens	Softens	Softens	(4)
Effect of cold water	None	None	None	None
Water absorption, percent in 24 hr. at 25 deg. C	0.05–0.15	1.5–4.0	.....	.....
Water extraction, percent in 24 hr. at 25 deg. C	.....	.....	.....	0.20
Resistance to:				
Weak acids	Excellent	(1)	Excellent	(2)
Strong acids	Excellent	(1)	Excellent	(2)
Weak alkalies	Excellent	(1)	Excellent	(2)
Strong alkalies	Excellent	(1)	Excellent	(2)
Alcohols	Excellent	(1)	Excellent	(2)
Ketones	Dissolves	Dissolves	Dissolves	Dissolves
Esters	Dissolves	Dissolves	Dissolves	Dissolves
Aromatic hydrocarbons	Swells	Swells	Swells	Swells
Aliphatic hydrocarbons	Excellent	Good	Excellent	(2)
Mineral oils	Excellent	Good	Excellent	(2)
Animal oils	Excellent	Good	Excellent	(2)
Vegetable oils	Excellent	Good	Excellent	(2)

* Properties shown reflect characteristics of certain specific formulations. Physical, mechanical, electrical and corrosion-resistant properties may be varied by modification or by use of other compounding materials.

† All constants in plasticized Tygon vary according to specific applications. Data are an average figure on a typical Tygon sheet.

(1) These properties may vary greatly, depending on the composition, types and amounts of fillers.

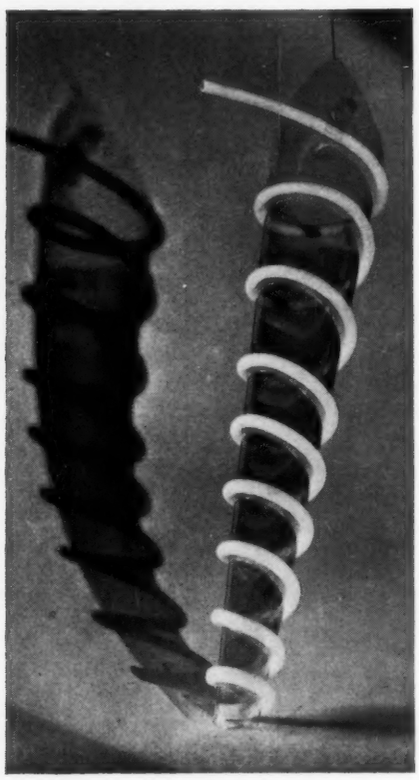
(2) Dependent on type and amount of plasticizer used.

(3) Electrical properties depend on choice of plasticizer and fillers.

(4) Wet or dry heat affects the stability of Tygon depending on type and amount of stabilizer.

softer compounds can be lathe cut and ground. No absolute physical values can be tabulated because properties vary widely according to the base resin and the amount and type of plasticizer used. Certain formulations will burn when they are held in contact with a flame, but the burning will stop when the flame is removed.

PAINT. Used in conjunction with Tygon primer, Tygon paint adheres readily when applied to properly prepared surfaces. It may be sprayed, dipped or brushed and dries quickly to a hard, lustrous finish.



Tubing is available in either flexible or rigid forms, together with Tygon molded couplings, in a wide range of sizes and in varying wall thicknesses

VALVE DIAPHRAGMS. Use of Tygon in Saunders diaphragm type valves prevents the solution from harming the working parts of the valve by coming in contact with them.

GASKETS. Tygon sheets as gasketing material provide a corrosion-proof seal that will withstand abnormal pressures. Gaskets can be molded to exact dimensions and may be reinforced with various fillers for operation at higher temperatures.

INSULATION. Dielectric strength of Tygon is 35,000 to 50,000 volts per mm. and flexing life is 10 to 12 times that of rubber. These qualities, together with its inertness to oxidation and resistance to the action of oils, gasolines and water indicate Tygon's possibilities as an insulating material for wire and cable.

TUBING. Available in rigid or flexible form, together with Tygon molded couplings, in a wide range of sizes and in varying wall thickneses, Tygon tubing can be extruded to hairline and uniform accuracy. It can be made to withstand high pressures by multiple-braid reinforcement, will withstand freezing without bursting and will not scale or tuberculate. It can also be made in a non-toxic form so that it will not affect flavor or color in food and drug processing.

IMPREGNATION. Tygon lends itself readily to fabric impregnation by either dipping or pressure processes. Used for belting, Tygon impregnation or lamination is not susceptible to mildew or rot, is not affected by oil and will withstand repeated flexing without developing cracks or breaks. Used in place of rubber in gasoline hose it eliminates the inner fabric with its protective spiral wire, resulting in a hose that is lighter in weight, more flexible and less subject to deterioration and wear.

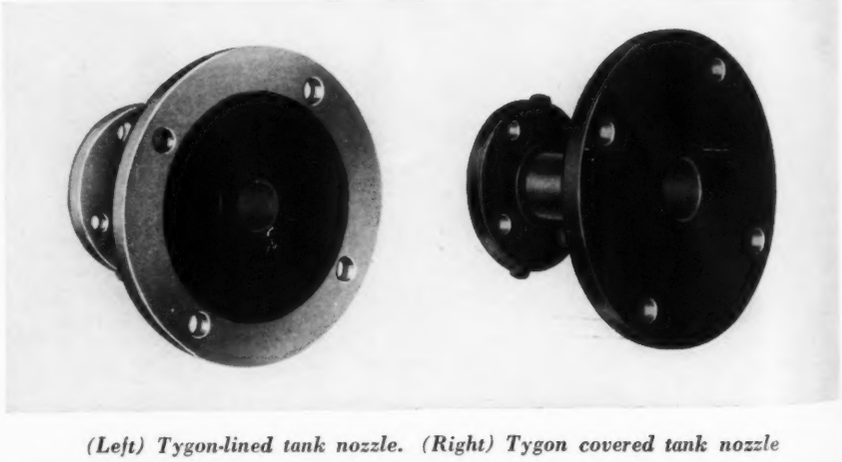
GLASS COATING. In a special formulation Tygon can be used as a shatter-resistant coating solution for glass. In this form it dries quickly to form a strong, flexible, waterproof coating which has sufficient adhesion to hold glass fragments together. The coating can be applied to either or both sides of the glass.

AVAILABILITY. War needs now limit the use of Tygon to essential purposes. Capacity expanded to meet these demands, however, will be available after the war to meet the needs of peace, when it is expected that even wider uses for and applications of the material will develop.

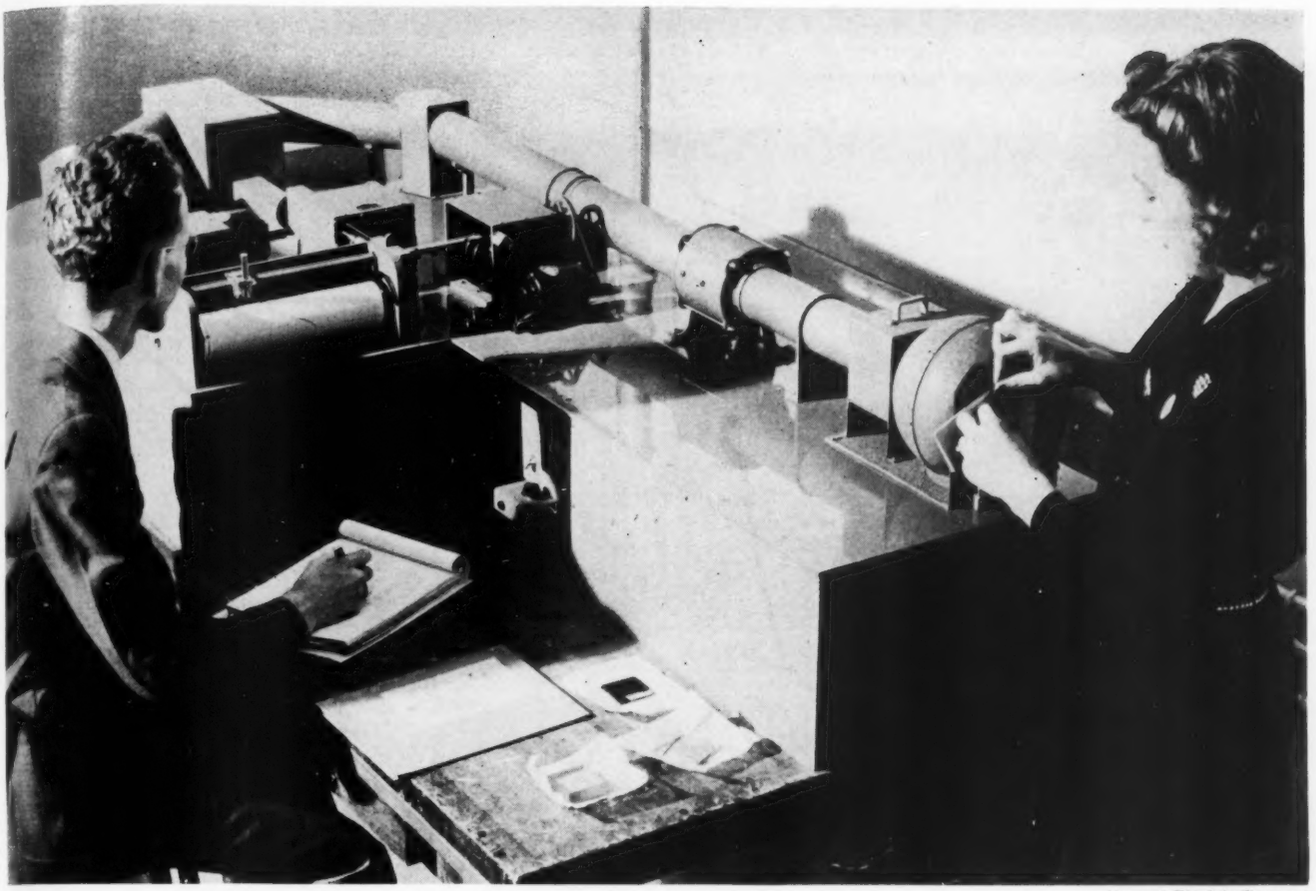
Chemical Resistivity of Tygon T

Solution	Immersion in solutions shown for 7 days at 25 deg. C.		
	Percentage change in weight	Percentage change in weight, subsequent exposure to air at 25 deg. C. and 50 percent relative humidity for 4 weeks	Effect on surface
30 percent sulfuric acid	0.04	0.00	None
3 percent sulfuric acid	0.09	0.00	None
10 percent nitric acid	0.08	0.00	None
10 percent hydrochloric acid	0.09	0.00	None
5 percent acetic acid	0.11	0.00	None
10 percent sodium hydroxide	0.09	0.00	None
10 percent ammonium hydroxide	0.16	0.10	None
10 percent sodium chloride	0.09	0.00	None
Distilled water	0.09	0.00	None
50 percent ethyl alcohol	0.07	0.00	None
Acetone	Dissolved	Dissolved in solution	Dissolved
Ethylene dichloride	Swelled*	Decomposed by swelling*	Dissolved
Toluene	79.0*	16.00*	Soft, rubbery
Gasoline	−0.01	0.00	None

* Can be handled by Tygon F.



(Left) Tygon-lined tank nozzle. (Right) Tygon covered tank nozzle



General Electric Company

The spectrophotometer is the basic instrument for the fundamental standardization of color

Common Language of New Standard Simplifies Color Specification

For technical purposes color standardization and specification have been practiced for more than 20 years, but there has been no universal method for specifying color. The new A.S.A. standard recognizes the correlation between the basic system and the more easily comprehended system based on the Munsell "Book of Color." Familiarity with both systems greatly simplifies the specification and interpretation of color by all groups that work with it.

ACCURATE specification and description of color has been a scientific reality for the past 20 years or more, but the basic system used has been so technical that only the groups who have worked with it knew what was meant. Chemists have used the term "color" to describe a property of dyes, pigments and such materials. Physicists have used the word as a description of certain optical phenomena. And the psycho-physiologists have used the term to denote a sensation in the consciousness of an observer. Each group has had its own language, despite an almost unanimous purpose.

The gaps between the language of these groups have finally been closed by the adoption of a war standard for "Specification and Description of Color" by the American Standards Association. Now all groups interested in color have a basis for describing color in terms that can be mutually understood. The standard provides:

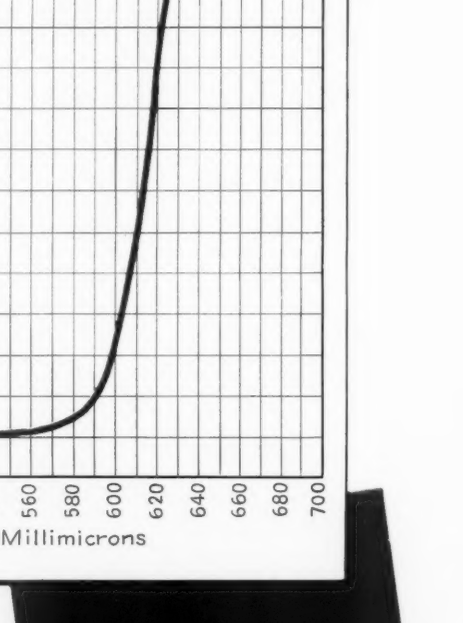
I—PURPOSE

To recognize and recommend a basic method for the specification of color, and to facilitate its interpretation.

II—PROVISIONS

1. The spectrophotometer shall be recognized as the basic instrument in the fundamental standardization of color. (Specifications of spatial distributions of the incident and collected light are essential to the standardization of spectrophotometry. Until standard conditions are established by agreement, the particular conditions employed in each instance should be stated clearly.)

2. Color specifications computed



(Above) Spectrophotometric chart for International Printing Ink's U.S.A. Silk Flag Red. (Right) International Printing Ink's U.S.A. Silk Flag Red. Tristimulus values are X = 0.21703, Y = 0.12742, Z = 0.05307. Trichromatic coefficients are x = 0.5460, y = 0.3205. Monochromatic specifications are λ = 613.8 mμ % R 12.7, % P 64.2. Munsell notation, 5.5 R 4/14

from spectrophotometric data shall be found by means of the standard observer and co-ordinate system adopted in 1931 by the International Commission on Illumination.

In the absence of a special reason for adopting some other illuminant in reducing spectrophotometric data, standard International Commission on Illumination illuminant *C*, representative of average daylight, shall be used.

The basic specifications of color shall consist of the tristimulus value *Y*, and the trichromatic coefficients *x* and *y*, of the International Commission on Illumination co-ordinate system, or they shall consist of the tristimulus value *Y* and the dominant wavelength and purity.

3. For the popular identification of color, material standards may be used. The only system of material standards that has been calibrated in terms of the basic specification is represented by the 1929 edition of the Munsell Book of Color. The use of this book is recommended wherever applicable to the specification of the color of surfaces. Approximate identifications of Munsell hue, value and chroma may be secured by direct visual comparison with the samples in the 1929 Munsell Book of Color. When the most accurate visual comparisons are needed, the mask method is recommended. Wherever more exact Munsell notations are desired, they shall be found from the basic specifications *Y*, *x* and *y* by interpolation among the smoothed curves for Munsell hue, value, and chroma. (Most surfaces whose colors fall outside the range covered by the samples of the 1929 Munsell Book of Color cannot be assigned Munsell notations by reference to the smoothed curves. For such surfaces, for transparent media, and for illuminants, only the basic specification *Y*, *x* and *y*, or *Y*, dominant wavelength and purity are recommended.)

4. A descriptive name according to the Inter-Society Color Council—National Bureau of Standards system of color designation may be derived from the Munsell notation. This name is recommended wherever general comprehensibility is desired and precision is not important. The use of color names for color specification is not recommended. (It should be emphasized that the Inter-Society Color Council—National Bureau of Standards names are descriptive only and are not adapted to sales promotion nor intended to replace names that are developed for that purpose.)

The alternative, but coordinated systems of color specification described in 1, 2 and 3 are each adequate for specification of color tolerance in those cases for which each system is useful and convenient. As in all engineering specifications, the tolerances in different industries vary and depend upon the uses for which the products are intended. Color specifications according to 2 and 3 are, strictly speaking, appropriate only for products viewed by normal vision, but in the absence of agreement on standards for anomalous color vision or vision at low illuminations no more appropriate color specifications are available.

A list of references is well worth study by anyone not familiar with colorimetric principles.

The standard also explains that dominant wavelength and purity are obtainable by computation from the trichromatic coefficients *x* and *y*. Several methods of expressing purity have been proposed and used to some extent. In this standardization, purity refers to the quantity which is called excitation purity in discussions of the several possible purity scales. For the sake of uniformity, the symbol, *p*, and expression in terms of percent is recommended for purity. Likewise, when *Y* is specified in terms of reflection factor it should be expressed in percent, symbol, *R*. It is customary to express dominant wavelength in millimicrons, *mμ*, and this practice is recommended, together with the symbol, λ.

The request for approval of the standard was sponsored jointly by the General Electric Company and the Interchemical Corporation, both of which for many years have devoted much attention to the fundamentals involved. The General Electric Company pioneered in the marketing of a commercial model of the recording spectrophotometer as invented by Dr. Arthur C. Hardy, professor of optics at the Massachusetts Institute of Technology. The Interchemical Corporation has pioneered in the use of the spectrophotometer to establish standards of color for inks, pigments, paints, lacquers, enamels and other protective and decorative finishes, highlighted by the publishing in 1935 of "Three Monographs on Color."

Acknowledgement is made of the valuable help and advice given in the preparation of this discussion and interpretation of the new standard by Walter Granville, in charge of colorimetry research, and George Welp, advertising manager, of the Interchemical Corporation.

Familiarity with the various terms used in the standard is the first requisite for any one who would make proper use of it. A careful study of the references listed in the standard would be a good practical education in color engineering. But for those who deal with color as only one important phase of their work this might not be feasible. The following explanation and interpretation of the standard is intended to familiarize those who have not the time nor necessity for going into the entire subject of colorimetry.

In order to understand properly this discussion one must think of color as a combination of light and a sensation produced by receipt of that light by the eye and the interpretation of that sensation into an experience by the brain. The visible spectrum may be arbitrarily divided into six broad regions, even though the color of the spectrum actually varies continuously throughout its length. The physical difference between these regions is merely one of wavelength and this wavelength varies continuously from one end of the spectrum to the other. The unit of length commonly used for specifying wavelength of visible energy is the millimicron ($m\mu$), which represents one one-millionth of a millimeter. In terms of this unit, then, the spectral regions are approximately:

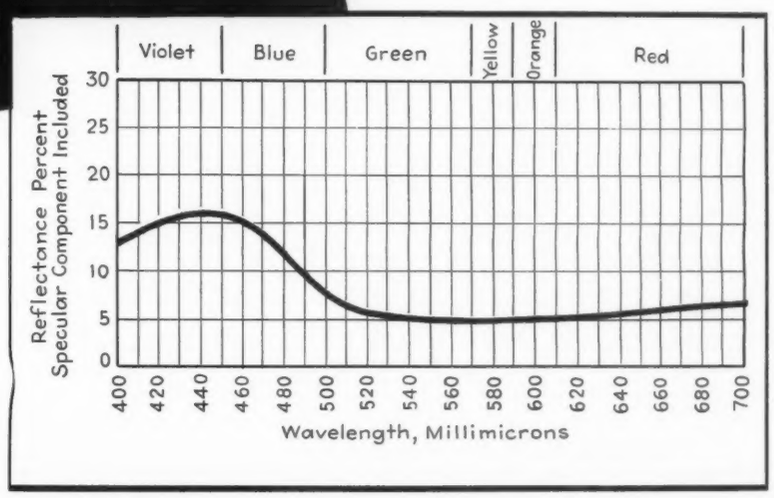
Violet	380-450 mμ
Blue	450-500 mμ
Green	500-570 mμ
Yellow	570-590 mμ
Orange	590-610 mμ
Red	610-770 mμ

The extremes of this wavelength range constitute the limits of color which the average eye can distinguish.

A spectrophotometer, used in the fundamental standardization of color under the new standard, measures the reflecting ability of a sample under controlled lighting conditions in relation to a nearly perfect standard. The standard is usually magnesium oxide, which is as near to perfect white that it is practical to reach. The results of this comparison are then charted by the spectrophotometer, resulting in what is known as a spectral reflectance curve. For purposes of reference and illustration in this discussion two of these charts, one for a printing ink known as U.S.A. Silk Flag Red and the other for a printing ink known as U.S.A. Silk Flag Blue, are shown herewith. Light is passed through a prism, producing an image of the spectrum which is then broken down by having a slotted piece pass vertically across the image. As the slit passes through the spectrum image it allows only a small portion of the image to pass through. This portion is split into two components, one illuminating the sample and the other illuminating the standard. As the slit passes across the spectrum image a comparison of the light reflected from the sample and standard is then made for each portion of the spectrum. The comparison is plotted as a percentage of reflectance of each portion of the spectrum.

All other calculations in determining the necessary information are made from the data in this reflectance curve. Before proceeding, however, the "standard observer" and "co-ordinate system" should be explained.

The "standard observer" is the result of much research which started nearly 100 years ago and culminated in the summarizing and publishing of results in 1922 by the Colorimetry Committee of the Optical Society of America. What it amounts to is that an observer looks into an optical instrument containing a suitable photometric field. The light whose color is to be matched is introduced into one-half of the field and the light from three primary sources is introduced in controlled amounts into the other half. The controls are then manipulated until a setting is found where an exact color match between the two fields is found. Thousands of such observations were made and the final data is an average of the results obtained. This average is the standard observer. The "co-ordinate system" is merely the



(Below) Spectrophotometric chart for International Printing Ink's U.S.A. Silk Flag Blue. (Left) International Printing Ink's U. S. A. Silk Flag Blue. Tristimulus values are X = 0.07291, Y = 0.06129, Z = 0.17283. Trichromatic coefficients are x = 0.2375, y = 0.1996. Monochramatic specifications are λ = 464.2 mμ, % R 6.1, % P 41.9. Munsell notation, 8 PB 2.2/6

mathematical method by which the trichromatic coefficients are determined.

The standard observer and co-ordinate system were adopted by the International Commission on Illumination in 1931 at a meeting at which international standards for color measurement were established.

From the standard observer data certain values have been established which form one of the basic specifications in the new standard. By calibrating the controls during photometric color-matching observations the amount of each primary in the unknown color can be determined. The unknown color can then be specified by X, Y and Z, each representing the amount of one of the primary stimuli. These are known as tristimulus values. They have already been determined for each wavelength of the spectrum and sets of values were adopted by the International Commission on Illumination.

Actually, the observer data obtained were transformed mathematically to a set of three primaries lying outside the realm of real colors. The value of X represents the amount of a primary which is a reddish-purple of higher saturation than any obtainable color having this hue. The value of Y represents the amount of a green primary considerably more saturated than the spectrum color whose wavelength is 520 $m\mu$. The value of Z represents the amount of a blue primary that is considerably more saturated than the spectrum color whose wavelength is 477 $m\mu$. These three primaries are interrelated and were chosen so that the Y function corresponds exactly with the visibility curve for a normal eye.

Three different illuminants were adopted as standards by the International Commission on Illumination. They are known as Illuminants *A*, *B* and *C*. The first represents a source having an energy distribution similar to that of a gas-filled tungsten lamp. The second represents approximately mean noon sunlight. The third is a combination of a tungsten lamp and a filter which produces light that is representative of average daylight and is the one adopted as standard by the American Standards Association.

Determination of tristimulus values involves considerable computation. Much of this is simplified, however, by the use of tables already computed and published in the proceedings of the International Commission on Illumination and Professor Hardy's "Handbook of Colorimetry." The method for determining tristimulus values consists, briefly, of reading the reflectance values (R) of the sample involved at regular intervals of 5 or 10 $m\mu$. These are then multiplied by the corresponding tristimulus values (X, Y and Z) for spectrum colors weighted by the energy distribution of Illuminant C. This latter data can be read from the tables mentioned above. The results of the multiplication are then added, the result being the tristimulus values X, Y and Z, respectively, for the sample.

Trichromatic coefficients are measures of the quality of a color, or its chromaticity. They are determined from the tristimulus values by using the following equations:

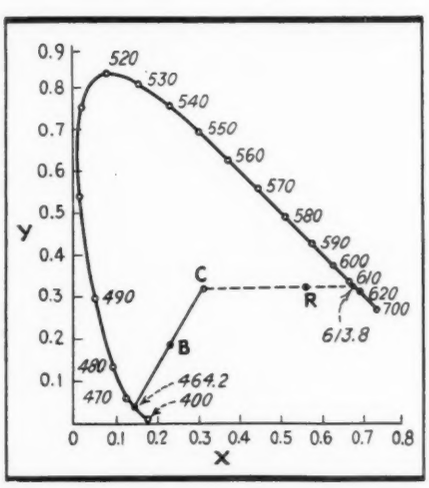
$$x = \frac{X}{X + Y + Z}$$

$$y = \frac{Y}{X + Y + Z}$$

$$z = \frac{Z}{X + Y + Z}$$

Regardless of the values assigned X, Y and Z the sum of $x + y + z$ is always 1. Therefore, only two of these values are needed for specification purposes. The combination of values for trichromatic coefficients x and y and the tristimulus value Y, together with a reflectance curve, are sufficient data for a colorimetric expert to reproduce the exact color used originally, provided the same illuminant is used. Through practice, however, a person is able to visualize approximately the color specified when tristimulus value Y, dominant wavelength and purity are given. This is extremely difficult with the former specification. Because the Y function corresponds exactly with the visability curve for a normal eye this is the only tristimulus value necessary for a specification. The others are used, however, for computing necessary data.

Dominant wavelength is easiest determined by graphic representation. The trichromatic coefficients x and y of the spectrum colors are plotted and a curve is drawn through the points, as shown in the diagram. The illuminant and the sample are located on this diagram and connected by a line that is extended to the spectrum locus. The point where this line intersects the spectrum locus indicates the dominant wavelength.



Dominant wavelength and purity are determined from a chromaticity diagram

Purity is also determined from this chart. It is simply the distance of the sample point from the illuminant point in relation to the distance from the illuminant point to the spectrum point. The dominant wavelength and purity of the two colors used as illustrations are indicated on this chart.

The "Book of Color" published by the Munsell Color Company has long been widely used for identification, description and specification of color. It contains more than 400 different color chips notated in terms of hue, value and chroma. Hue is that quality of a color by which it is distinguished from another. Value is the quality by which a light color is distinguished from a dark one. Chroma is the quality by which a strong, or brilliant, color is distinguished from a weak, or grayish, one.

A system of identification of these colors and their variations has been established and is now in common use. It will be noted in the captions for the illustrations that the Munsell notation for the red is 5.5 R 4/14 and for the blue is 8 PB 2.2/6. These data indicate where to find chips of these colors, or the nearest thing to them, in the Munsell color book. The red is 5.5 in hue, 4 in value and 14 in chroma. Similarly, the blue (a purple-blue) is 8 in hue, 2.2 in value and 6 in chroma.

Descriptive names for numerous colors have been established by a system developed by the Inter-Society Color Council and the National Bureau of Standards. This is the system referred to in section 4 of the standard. The system is recommended only for general designation of colors and not for specification work. Neither is this system intended for sales promotion or advertising.

Lord Kelvin is credited with saying "When you can measure what you are speaking about, and express it in numbers, you know something about it; and when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science whatever the matter be." Thus, the specification and description of color has been raised to the level of science.

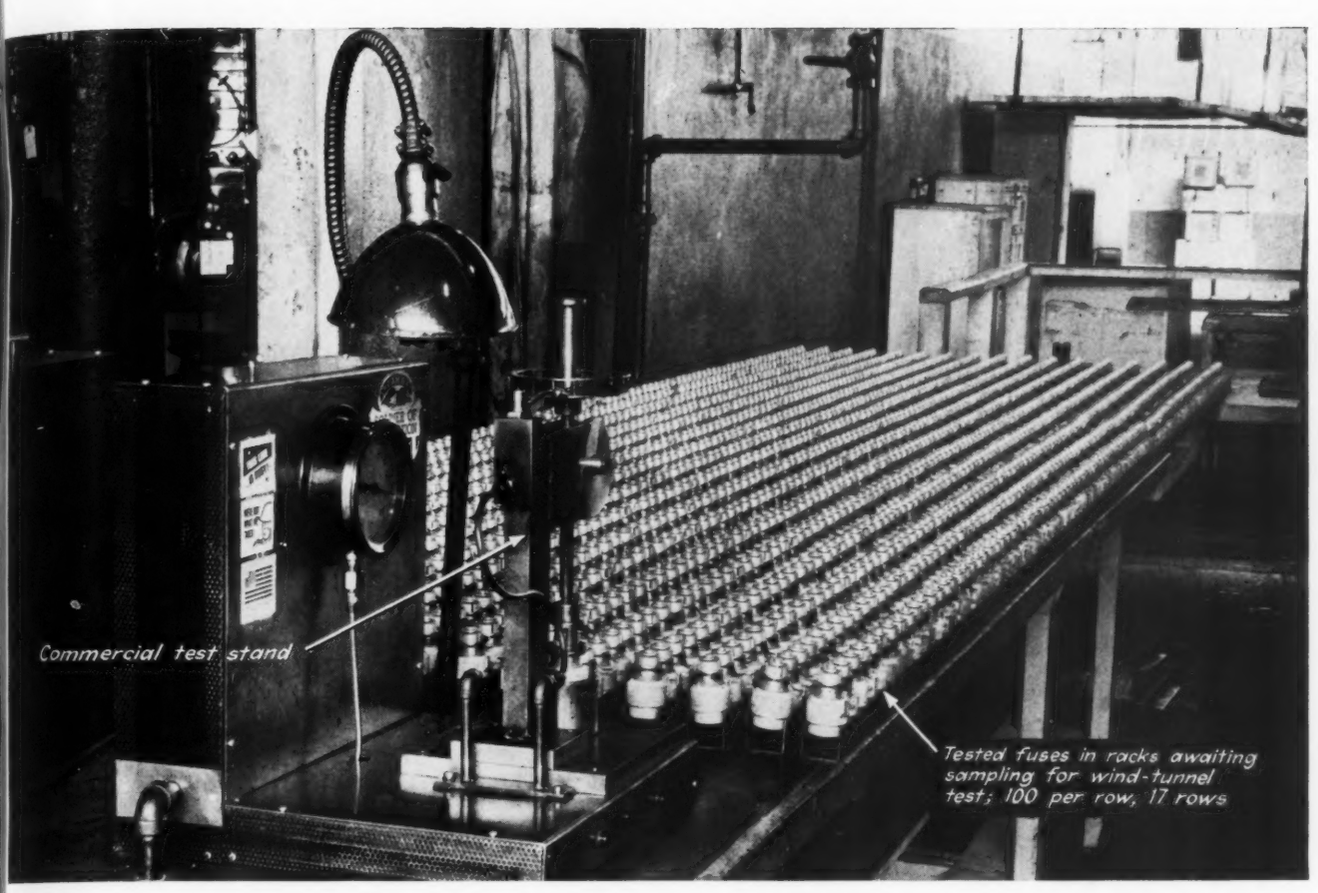


Fig. 1—Commercial test and storage racks. As the fuzes pass final test they are placed in the racks in order, the first rack being completely filled, then the second, and so on. Thus the fuzes are kept in the order in which they are inspected at the commercial test station

Wind Tunnel Test Specifications For Quality Control of Bomb Fuzes

A. L. ATHERTON
Manager, Quality Control
Westinghouse Electric & Manufacturing Company

Danger and the cost of the final step in the delivery of bombs to their ultimate destination makes it highly important that the fuzes which control detonation be of the greatest possible dependability. This has led to the adoption by Westinghouse of a system of sampling checks beyond those required in the original specifications.

BOMBS, with their fuzes, are dropped out of planes flying at speeds up to several hundred miles per hour. As they leave the plane, they suddenly strike the still air while they are traveling at the plane speed. There is an impact of high velocity air against the vane resulting in a sudden high torque and high rotational velocity. The commercial test, applied to each fuze in accordance with specifications, consists of slow speed operation to determine merely that the mechanism turns freely. The use of this limited test places dependence for all operating characteristics of the assembly, except for freedom of action, on the control of parts manufacture.

Experience shows that any product of mass production methods is subject to variations in spite of any degree of control of parts manufacture which can be practically applied. This is particularly true under today's conditions of unusual demands on industry which make it necessary to use, in some operations, personnel without the skill and experience which goes with many years of such work. Under these conditions, we need a test which simulates the conditions of operation as closely as possible.

During the development of a product, the development engineers invariably make all kinds of tests, covering the whole range of anticipated operating requirements and conditions, so that they know—not guess—just what are the capabilities and limitations of the

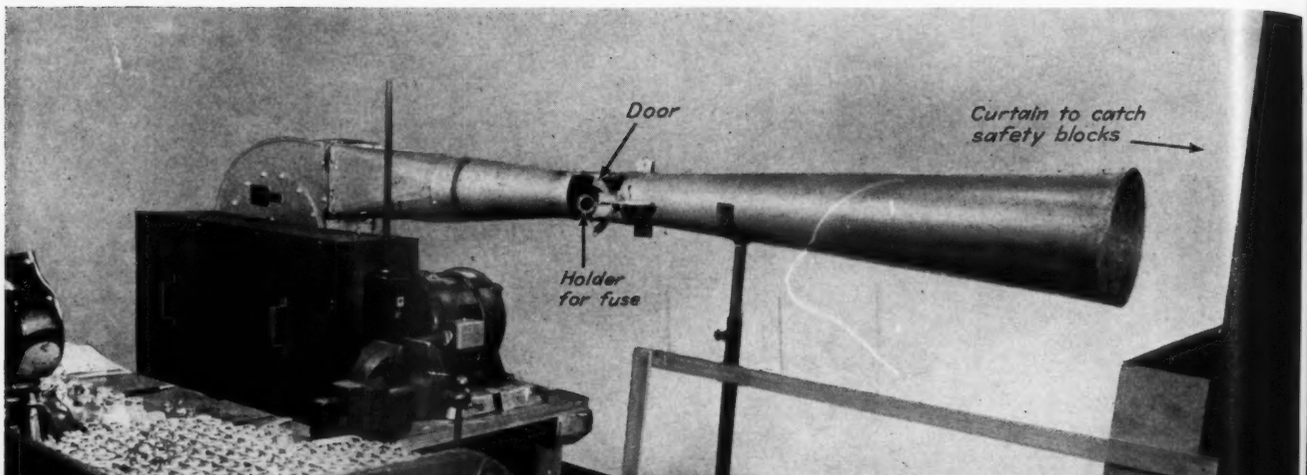


Fig. 2—Wind Tunnel for tests up to 250 mi. per hr. This is a conventional wind tunnel in which the blower delivers air continuously to the tunnel, the velocity being controlled by varying the size of inlet port. The fuze is mounted in a holder on the door and the propeller is prevented from turning by a wire projecting through the tunnel wall. When the test starts, the wire is withdrawn and the full force of the vane is suddenly applied to the mechanism

product. Those responsible for quality control of the product in manufacture can not reasonably do less. Complete checks of each piece produced are neither practicable nor necessary but the needs can be fully met by tests on a small sampling and intelligent analysis of the result. One critical element in the operation of the fuzes is the time required for the spinning vanes to arm the fuze, that is, release the locks that prevent its operation.

The test procedure adopted for checking arming time consists of testing a sample of the production of each assembly shift in a wind tunnel at air velocities up to the limiting velocity of the wind tunnel, recording the time required for the fuze to arm at each velocity, and maintaining a record of the time values to detect any significant trend in either the average values or the variations. In addition, each fuze so tested is completely dismantled and all parts checked for any indication of abnormality, particularly in the effects of operation.

A wind tunnel test approaches operating conditions but does not completely duplicate them because of the variation in the direction of air flow against the vane as the bomb tumbles during the first few hundred feet of its fall and before the tail vanes have straightened its flight. However, comparisons between results of wind tunnel tests and the meagre results which are available from actual dropping tests indicate a sufficiently close correspondence of re-

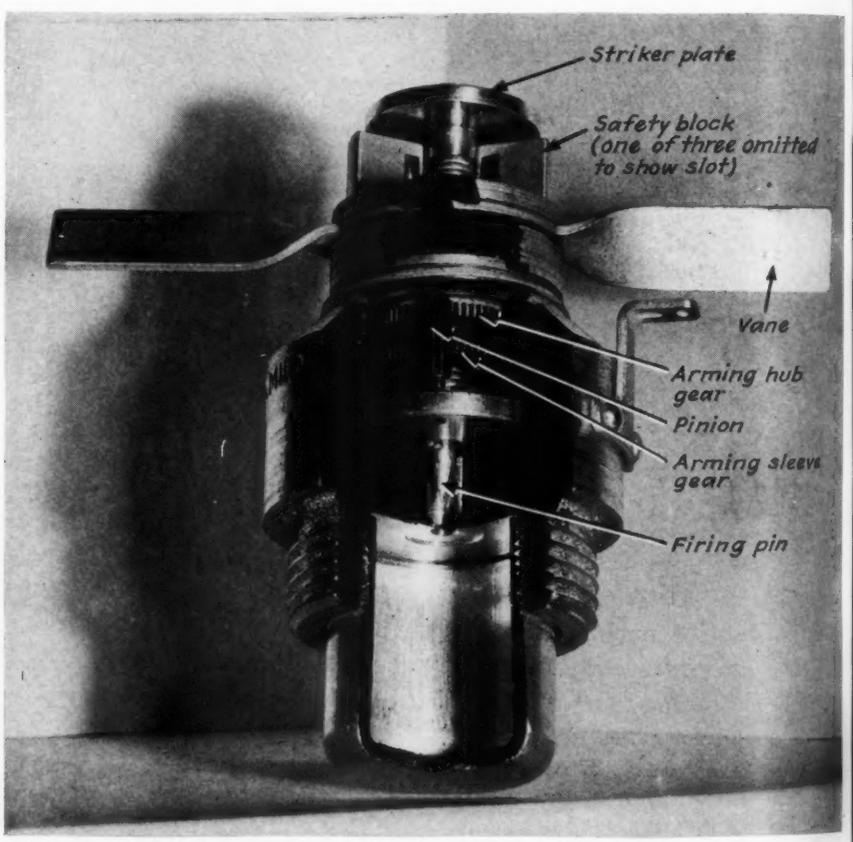


Fig. 3—Enlarged photograph of a "cut-away" fuze. Relative motion of the fuse in the surrounding air results in turning the vane which is directly connected to and thus drives the arming hub. This drives the pinion and in turn the sleeve. The speed of the sleeve is slightly different from that of the hub due to the difference of one tooth in the two gears and this differential velocity of the sleeve and hub results in withdrawal of the sleeve from the slots in the safety blocks, ultimately releasing them to fly out centrifugally. When the safety blocks are out, the fuze is armed and will be detonated on impact

sults to justify placing considerable dependence on the results of the wind tunnel test.

The application of such tests, to make them as fully representative of the entire production as is feasible, is systematized in coordination with the manufacture. As the fuzes are assembled they are delivered to the commercial test station in time sequence by sliding them along metal channels into which they had been placed by the final assembly operators. After the commercial test, they are placed in temporary storage racks, in the same order. The position of the fuzes in the racks thus represents the order in which they were assembled. A sample taken from specified positions in the racks thus represents the entire production of an assembly period during which the racks were being filled.

Two kinds of information are available from the results of wind tunnel tests on any given sample. The over all result, as compared with previous history, gives an indication of the quality of the sampled batch of approximately 1,500 fuzes. Any deviation from normal, together with results of further local sampling, gives an indication as to whether the abnormality was a chance "freak" occurrence or whether it was significant of a change affecting the quality level.

In considering the results, several facts must be kept in mind: (1) the wind tunnel tests are carried up to the limiting velocities at which it is intended to use the fuzes and (2) the results of such tests, verified by "dropping tests," may indicate that the design needs modification to meet recent change in conditions of field use. Both of these considerations lead to the expectation that some failures and a considerable range in variation in results will be encountered.

If no significant deviation from normal results are found in the production lot sample, the lot is passed for acceptance and shipment.

If any fuze fails to arm or requires an arming time longer than a more or less arbitrary limit of five seconds at 250 mi. per hr., the adjacent fuzes, 100 just prior to and 100 just after the faulty one, are checked by duplicate wind tunnel tests on six fuses from each hundred, that is, the 1st, 20th, 40th, 60th, 80th and 100th. If this recheck shows no abnormalities, the original defect is considered a "freak." If the recheck shows some further defects, and if the percentage of defects exceeds the percentage of failure to be anticipated from previous experience, this is considered to be an indication that the control of parts manufacture has failed to give complete protection and an investigation is instituted as to the cause of the trouble and the correctives required.

In the course of experience since this system was adopted, it has been effective in detecting, and leading to the correction, of several faults which were not detected by the commercial test nor by the rather complete system of control of parts manufacture and which would have resulted in shipment of large number of fuzes of less than the maximum quality.

For example, at one time, the coating

Fig. 4—Wind Tunnel for velocities higher than 250 mi. per hr. The general scheme of this tunnel follows, in general, one described to the author by E. S. DeHart of Peco Manufacturing Company. This wind tunnel consists of a storage tank for high pressure air, up to 200 lb. per sq. in., a reducing nozzle to control the rate at which the air is released, a quick acting valve to start and stop the air flow, an automatic timer to measure the duration of air flow, and a pressure gauge to indicate tank pressure before and after operation. After calibration, the wind velocity can be directly calculated from the change in pressure and the time during which the valve is open. With this arrangement, the air flow during any given test varies from the maximum at the start, when the air pressure is maximum, to a lower value at the end but for these short tests of a second or two, the change is not great enough to affect the value of the results seriously. For example, to give 500 mi. per hr. average velocity for one second, the pressure is set to give an initial velocity of approximately 540 mi. per hr. and will decrease during one second operation to a pressure which will give a velocity of 460 mi. per hr. and an average of very closely 500 mi. per hr.

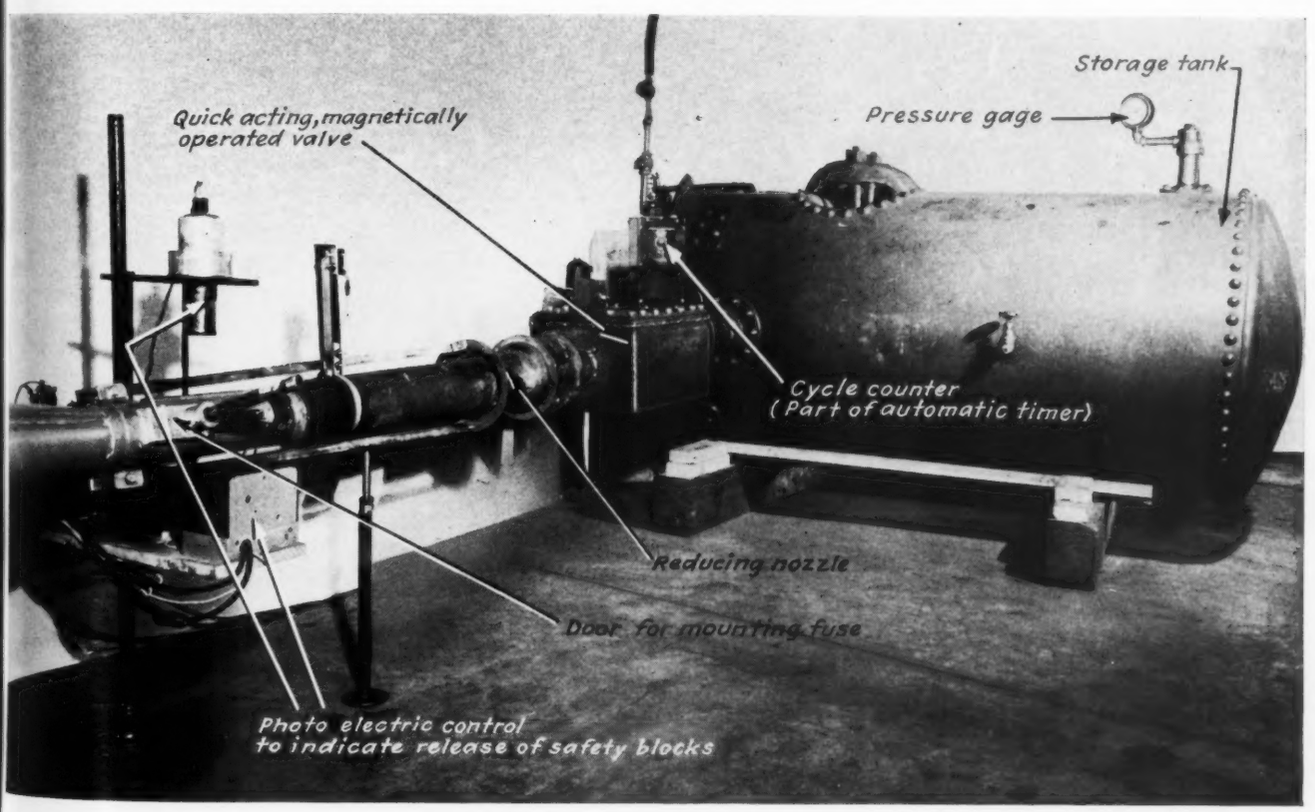
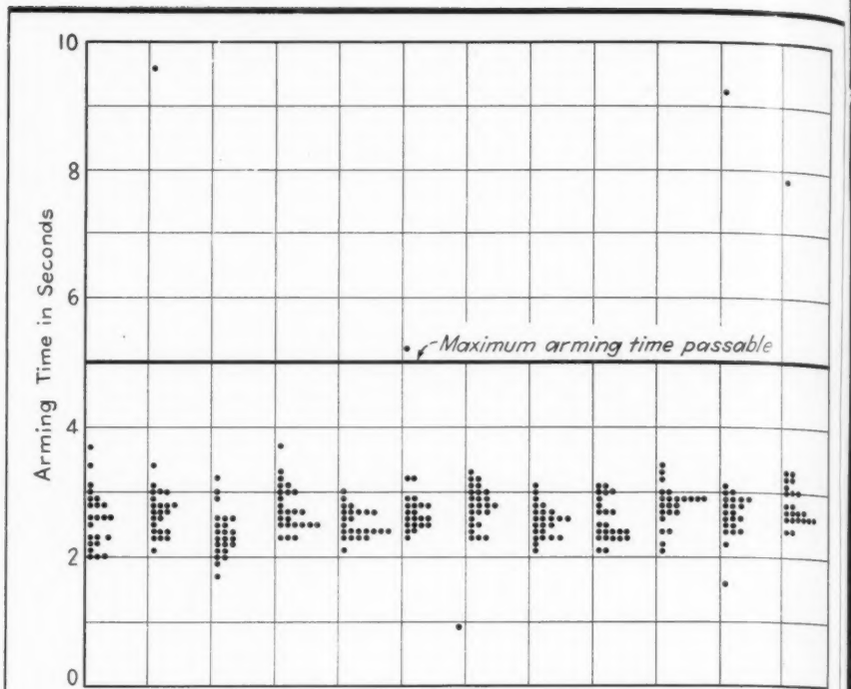

Storage tank
Pressure gage
Quick acting, magnetically operated valve
Cycle counter (Part of automatic timer)
Reducing nozzle
Door for mounting fuse
Photo electric control to indicate release of safety blocks

Fig. 5—Wind tunnel test records. This chart shows the arming time at 250 mi. per hr. of 25 fuzes per day for 12 days. Each dot represents one fuze. The solid line at 5 sec. represents a "limit for action." A single fuze above this line in one day's sampling is probably a "freak"; more than one is probably an indication of trouble. Any significant change in average or in distribution pattern also indicates the need for investigation



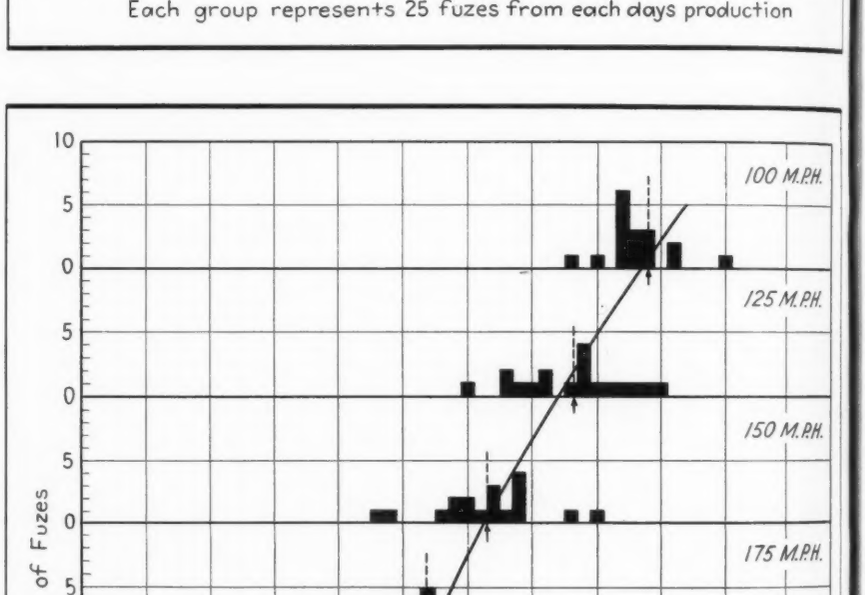
of graphite applied to the gears and the running threads on the arming sleeve and hub became contaminated with tiny particles of foreign material. This did not affect the passage of the fuzes through the commercial test but it did show up in abnormally long arming times in the wind tunnel test and this led to an investigation which disclosed the source of trouble and resulted in the dismantling and rebuilding of several thousand fuzes which would otherwise have been shipped and used, though of sub-normal quality.

In another instance, the wind tunnel test clarified thinking on a point which had been the source of some uncertainty and controversy. It was noted that when some of the fuzes were operated by hand, the meshing of the individual gear teeth could be felt, while on others this was not the case. Wind tunnel tests of the two kinds disclosed a greater uniformity in high speed operation for those in which the gear action could be felt, and emphasized the importance of close meshing of the pinion with the hub and sleeve gears.

The wind tunnel tests also led to a recognition of the wide variation which occurs in arming times under the original system of assembling the fuzes with the sleeve and hub gears in contact and then backing off two and a half turns. A study disclosed that the amount of sleeve and hub threads left in engagement varied over a quite wide range causing corresponding variations in arming time. By setting the fuzes to give a definite projection of the sleeve above the nut, which projection determines arming time, all effects of tolerances on the arming time were eliminated.

Over all, the use of this "super check" by wind tunnel tests has proved of great value and has resulted in a quality level far above what would have been otherwise attained.

Fig. 6—Wind tunnel test records. This chart records one part of a study of the arming time at various wind velocities. Each blacked square represents a fuze. Arrows indicate average values for all tests on each velocity. The solid curve passes almost through all average values. The distribution at each velocity is an indication of the degree of uniformity



Finishing Aluminum Parts For Military Aircraft

Protective coatings for aluminum parts in military aircraft are subject to specifications that are as rigorous as those applying to the selection and use of any material employed in the aircraft structure. In this field the purposes for applying organic protective coatings may include not only corrosion resistance, but improvement of aerodynamic properties, maintenance, tactical aid, means for identification, or for camouflage purposes.

ALL commercial aluminum alloys possess corrosion-resistance properties, but the various alloys differ in their degree of resistance. Also, the presence of corrosive agents varies with the kind of exposure. Therefore the type of protective treatment, if necessary, depends upon the characteristics of the particular alloy and also upon the properties required to withstand service conditions.

With a few exceptions, unless otherwise specified, all aluminum alloy parts for military aircraft are anodized or receive a chromic acid dip treatment to provide effective paint adhesive properties to their surfaces. The chromic acid dip treatment forms a film similar in character to the anodic film, but is so thin that, in itself, it is not considered sufficient protection. It is, therefore, essentially a treatment to improve paint adhesion. Anodic treatment is not applicable under the following conditions:

1. Parts or assemblies on which have been assembled other parts or accessories fabricated of dissimilar metals, such as brass, bronze, iron or steel.
2. Die-castings in which a dissimilar metal part has been integrally cast.
3. Parts or assemblies that contain copper as an alloying element in quantities in excess of 5 percent.
4. Tanks or other assemblies wherein impregnated fabric or water-tight or gas-tight sealing compounds have been inserted between the faying surfaces.

DEGREASING. Where large quantities of grease, oil, and scum have collected on aluminum or aluminum alloy parts, the first step in preparation for anodic or chromic acid dip treatment consists either of manual removal with a suitable solvent, soaking in a solvent, preferably non-volatile, or the use of a solvent vapor degreaser in which vapors of a stabilized trichlorethylene compound are permitted to condense on the parts in a specially constructed unit. For removal of paint, the parts are immersed in a hot solution of an approved paint stripping compound.

ALKALINE WASH. To remove other foreign matter, the parts are then cleaned in a silicate type alkaline wash solution containing no free caustic and having a satisfactory detergent action with no deleterious effect on aluminum or aluminum alloy parts. The compound should be equivalent to Navy Specification M-354. The cleaning solution is made by dissolving four to six ounces of the compound to one gallon of water. For best results, the temperature of the solution should be maintained at 180 deg. F. The solution should be continuously agitated while the parts are being washed. After a period of five to fifteen minutes in this solution, the parts are removed and then rinsed in clean hot water at 180 deg. F. If parts are properly cleaned, their surfaces should support a "non-break" water film.

PASSIVATING WELD FLUX. All welds in aluminum alloy parts should be cleaned by scrubbing in hot water. After a thorough scrubbing, the welds should remain in an unheated 10 percent solution of concentrated commercial sulphuric acid (66 deg. Bé.) for not less than half an hour. When cleaning welded gas tanks and other closed members, the solution should be agitated freely within the closure to make sure that all welded areas are reached. This acid solution counteracts or passivates any flux which remains after welding. After removal from the acid bath the aluminum alloy parts should be rinsed in hot water, and then dried completely.

ANODIC TREATED PARTS. After the hot water rinse following the alkaline wash, and passivation of the weld flux if necessary, all non-alclad aluminum alloy parts, sheet metal parts of alloys 17S and 24S, extrusions and forgings of alloys 14S, 17S and 24S, and castings of alloy 195 are given an anodic treatment. Under special instructions by a proper authority parts fabricated of 2S, 3S, 52S, 53S, 61S, and all alclads may be anodized.

The anodic treatment consists of immersing the aluminum alloy parts in a chromic acid electrolyte and passing an electric current through them, the parts forming the anode and the tank the cathode. The electro-chemical action forms films of aluminum oxide on the surfaces of the parts suspended in the electrolyte. This film of oxide possesses high corrosion resistance. The surface of the film is such that it promotes the adhesion of subsequent finishes.

In order to obtain maximum protection from the anodic coating, as much forming, milling and cutting as is practicable should be done on the parts prior to anodizing.

In general the parts should be completely immersed in the electrolyte during the anodic treatment. Parts should be suspended from the anode bar with clips, hooks, wires, baskets, or drilled containers made of only aluminum or aluminum alloy. When the size of the part prevents immersing it completely in the electrolyte, anodizing can be done by partial immersions, but care should be taken to have the successive treatments overlap. Also any suspension clips that grip previously anodized surfaces should have sharp-toothed jaws to insure satisfactory electrical contact, because the aluminum oxide formed by the anodic treatment is a non-conductor. If the clips do not come into contact with the chromic acid electrolyte, they need not be made of aluminum or aluminum alloy.

All parts should be anodized in detail before assembly, except those parts assembled by welding and parts which will not be stressed. Disassembly should not be required when: (1) the assembly as finally placed in the structure will not be exposed to water or moisture, (2) there are no dissimilar metals

in the assembly, (3) the assembly is a unit that will not be disassembled in service, (4) waterproofing or insulating fabric compounds are not present which the electrolyte would deteriorate, or (5) the final organic coating forms a continuous unbroken film. All faying surfaces where moisture may enter and be held because of capillary action, of course, must be protected with an anodic film.

During the anodizing treatment the electrolyte should be agitated to prevent overheating of the anode. Agitation is especially important when anodizing parts which have rough surfaces or complicated shapes. On the other hand, agitation should not be overdone. When the electrolyte is overagitated, an anode may be impelled into contact with the tank wall thus causing a short circuit that will burn the aluminum part.

After anodizing, the parts should be handled as little as possible. When handling particular care must be taken not to soil the surface coating or to rupture the oxide film. Parts should not be handled with bare hands. Wire hooks or clean rubber gloves should be used wherever practicable. If the surface oxide is unavoidably soiled after anodizing it may be washed in a solution of sulphonated ether synthetic soap mixed with hot or warm water. No other cleaning agent should be used. After anodizing, the parts should be rinsed in clean water and then dried. When dry the parts should be sprayed immediately with a coat of zinc chromate primer.

CHROMIC ACID DIP TREATMENT. Unless otherwise specified, all aluminum alloy parts or assemblies, not to be anodized, fabricated from 2S, 3S, 52S, 53S, 61S, and all alclads, after the "alkaline wash" and clean water rinse, receive the chromic acid bath treatment. This consists of immersing the parts for five minutes in a 5 percent (by weight) solution of chromic acid. At all times during the treatment, the chromic acid solution should be agitated, and the bath temperature maintained at 130 deg. F. to 160 deg. F. After removal from the bath the parts are rinsed in clean hot water until all traces of the acid solution have been removed.

After the chromic acid etch treatment, all parts should be handled with clean rubber gloves. Care should be exercised to see that the etched parts are kept free of oil, grease, dirt, or other substances that might impair the paint adhesive properties of the oxide that has been formed on the surfaces.

Assemblies fabricated entirely of aluminum or aluminum alloy parts may be given the anodic treatment or the chromic acid bath dip whether the various parts have been joined by riveting or by means of resistance spot welding, provided that impregnated fabric or sealing compound has not been placed between the faying surfaces.

When dipping parts in the chromic acid bath, they should be suspended in the same manner as for anodizing, that is, by means of clips, hooks, wires, baskets, or drilled containers fabricated entirely of aluminum or aluminum alloy.

ALCOHOLIC - PHOSPHORIC ACID TREATMENT. When it is inadvisable to use immersion methods, surfaces of aluminum or aluminum alloy parts may be treated with an alcoholic-phosphoric acid solution which can be applied either by brush or spray. The solution is permitted to remain on the surface for a few minutes, then washed with clean water and dried. Zinc chromate primer or finish coat shall be applied immediately thereafter.

PRIMING. This process consists of the application of zinc chromate primer meeting Army Spec. 14080, Navy Aero Spec. P-27-B-2 or Spec. AN-TT-T-P-656. The primer is reduced about 200 percent with toluol or toluol substitute and applied by spray or brush to deposit a semi-transparent greenish yellow coat. A full hiding coat should be avoided. If the primed surfaces are not finished immediately, they should be cleaned before the application of the top coat.

COLOR COAT. After the application of the zinc chromate primer to the anodized or acid etched parts, color coats are then applied. For interior surfaces of passenger compartments, a darkened zinc chromate primer is generally applied. On exterior surfaces, a camouflage color coat is used. This coat may be either lacquer or synthetic enamel. Specification AN-TT-L-51 covers gloss lacquer materials. Army Specification 14105 and Navy Specification M-485 cover camouflage or nonspecular lacquers. Navy Specification E5 and Army Specification 3-98 or 14109 cover synthetic enamel, either gloss or camouflage. Aircraft materials of this nature have a finely dispersed pigment to give maximum smoothness. Regardless of whether lacquer or enamel is used, the finish must be nonspecular.

Fast drying synthetic enamels are to a great extent displacing lacquers because of the greater hiding power. One coat of enamel will, as a rule, cover as well or better than two or three coats of lacquer. Enamels may, when necessary, be used directly over the bare metal, which is not acceptable with lacquers.

All surfaces should be thoroughly cleaned and dry at the time of application of any organic coating. Parts should not be handled by dirty or greasy hands after the final cleaning operation. It is important that the oxide film be continuous and free from breaks, scratches, or other damage.

POLISHING. Gloss finishes may be polished and waxed with the commercial materials on the market.

CORROSION PREVENTION RULES

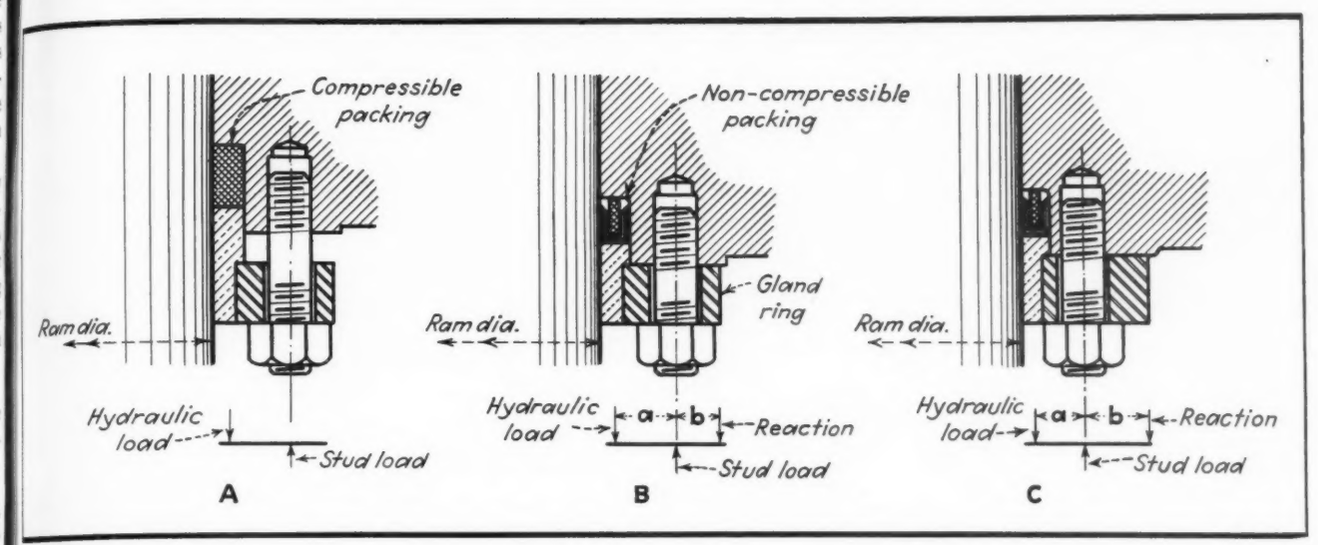
1. Avoid all dissimilar metal contacts. Chemical composition dissimilarity in contact sets up latent galvanic potentials that produce electrolysis. Therefore, contact between dissimilar metals is to be avoided wherever possible. Where necessary all faying surfaces should be insulated either with inserts or zinc chromate primer.

2. When dissimilar metal contacts are unavoidable, all faying surfaces should be protected by: (A) Anodizing the bare aluminum alloy in contact with other metal or material, including alclad. (B) Anodize all aluminum alloy rivets. (C) If in contact with steel surfaces, protect the steel surfaces by cadmium plating. (D) Corrosion inhibit all detail parts before any sub-assemblies. (E) Use zinc chromate primer as additional protection on all faying or contacting surfaces. (F) Copper alloys and steel parts in contact with aluminum alloys should be cadmium plated and then insulated as follows: Metal joints and seams should receive two coats of finishing material. The second coat may be either an additional coat of metal primer or a coat of aluminum varnish or lacquer.

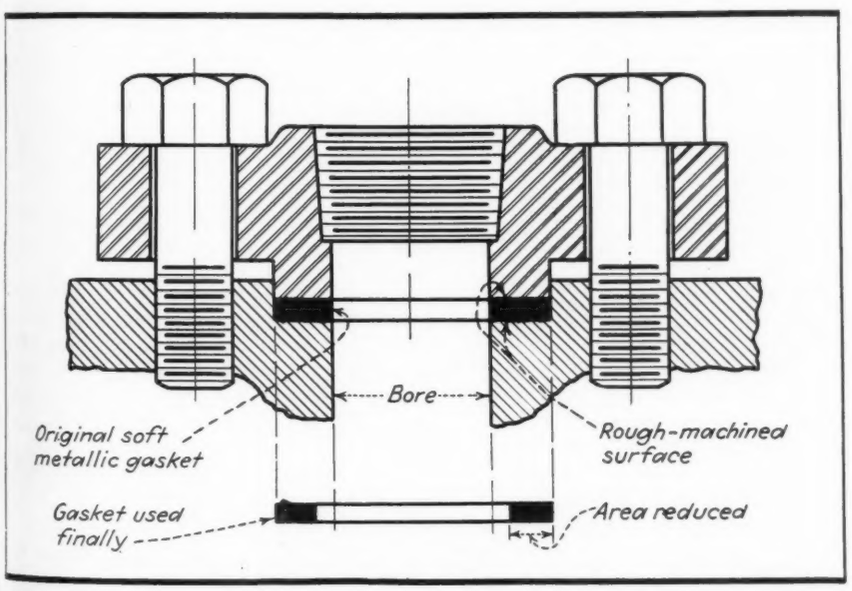
3. High purity aluminum alloys and alclads, whether or not exposed to weathering conditions, will resist corrosion for long periods, providing such surfaces are kept free of dust particles and continued exposure to moisture. Foreign bodies act as foci of corrosion, thereby setting up small local electrolytic couples which cause pitting. Such roughened surfaces are, thereafter, increasingly more difficult to keep clean and corrosion becomes general.

Material from which this article was prepared was submitted by F. A. Truden, process engineer, Vultee Aircraft, Inc.; J. Reinhardt, industrial subcontracting manager, Curtiss-Wright Corporation; and W. J. Montgomery, Sherwin-Williams Company.

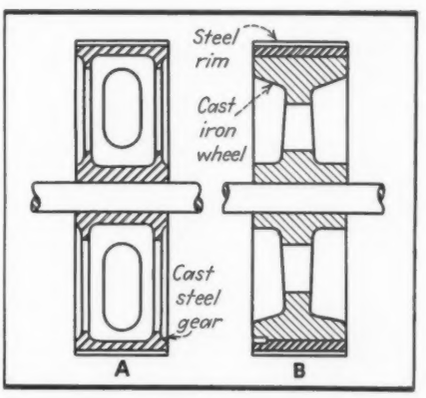
Causes and Cures



Large gland which had previously given good service with compressible packing, as shown at *A*, was redesigned to use automatic non-compressible packing as shown at *B*. Gland ring and studs were not altered. To everyone's surprise, the studs now failed consistently. It was finally realized that with no clearance between gland ring and stuffing box, the load on the studs was increased by a leverage effect $(a + b)/b$ as at *B*, the gland ring being of too large a diameter to effectively resist distortion. The load on the studs was greatly reduced by decreasing dimension *a* and increasing dimension *b*, as shown at *C*, and also by using a thicker gland ring.



Soft metallic gasket proportioned for high pressure by a design error was inserted in a low-pressure flange. Bolts were properly designed for low pressure. Despite the low pressure it was impossible to make a leak-proof joint because the bolts were not strong enough to deform the gasket. The condition was cured in the existing flange by increasing the gasket bore to reduce the area of the gasket, hence increasing the unit pressure on the soft metal. Future flanges will be made with a smaller spigot diameter. As a general rule gasket area should have a definite ratio to total net bolt area so that the gasket can be compressed beyond its yield point.



High-speed cast steel gear was made to usual slow speed proportions, as shown at *A*, to suit the loading conditions. Unit proved very noisy in service, so gear was replaced with a steel gear ring shrunk onto a heavy cast iron wheel as shown at *B*, thus preventing high frequency vibrations, both torsional and in the rim itself. Because of this and the damping effect of cast iron, the new gear was much quieter.

PRODUCT ENGINEERING will pay a minimum of $3 for each example published in Causes and Cures. Where illustrations are necessary, include drawings, rough sketches or photographs.

Better Brazed and Soldered Joints Made Possible by Induction Heating

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High frequency induction heating permits the specification of stronger, more uniform and more economical brazed and soldered joints in many applications. This article describes the basic principles of induction brazing, and presents data and typical examples showing how to design induction brazed or soldered joints.

FUNDAMENTAL advantages of high-frequency induction heating for brazing and soldering operations are that the heat can be closely controlled, can be confined to a narrow area, and acts fast. Because of these advantages, high frequency induction heating can give stronger, more uniform and cleaner joints at lower cost in many applications than can any other heating method.

For instance, a certain brazing operation on a piece of war equipment was previously done by gas torch. Because the highest quality joint was necessary, only highly skilled labor could be used. Great care had to be taken not only during the operation but in inspection as well. The average production time per joint was approximately 4 min. When high frequency induction heating replaced the gas torch, production time was reduced to 40 sec., women operators could be used, a uniform joint was achieved, and because of this uniformity inspection at this operation was eliminated.

Naturally, such ideal applications as these are by no means universal. However, where a brazed joint is of a type that lends itself readily to induction heating, the following advantages can generally be obtained: (1) Clean joints free from oxidation; (2) Stronger, more uniform joints; (3) Since heat is confined to small area around the joint, warpage and scale are minimized and the assembly can be more easily handled by workers; (4) Heating time greatly reduced; (5) Heating costs reduced; (6) Semi-skilled operators can be used; (7) Inspection costs and rejects reduced; (8) Fumes and smoke eliminated.

Induction heating is not new. For many years it has been known that by introducing a metal part into the center of a coil carrying alternating current, the metal would be heated. However, the application of this type of heating has been limited by equipment available. Motor-generator sets supplying frequencies up to 3,000 cycles have been available for approximately 20 years and have been used for melting, forging, and surface hardening. Due to the nature of the process involved, frequencies on this magnitude could not be used for many applications.

Generators capable of supplying power at frequencies up to 12,000 cycles per sec. have been developed during the past few years and have a wide application in the heating of relatively large steel parts. However, due to frequency limitations, even these machines cannot be economically applied to the heating of copper, aluminum, and small irregularly shaped brass and steel pieces. To supply the higher frequencies necessary for heating these parts, a spark gap oscillator was developed some years ago but its frequency limitation of approximately 200,000 cycles per sec. and its power limitation of approximately 15 kw. output restricted its use.

It has long been known that the vacuum tube oscillator could supply large amounts of power at the highest frequency desired. In the past several years vacuum tube oscillators have been developed that are built to industrial standards within an acceptable price range.

These oscillators depart drastically from radio construction practice. Using the simplest possible circuit, they are truly an industrial tool with emphasis placed on reliability, constancy of output, and low cost. By using conservatively rated elements, maintenance has been reduced to the periodical replacement of tubes, which when properly applied have expected lives of 10,000 hr operation. In most cases, the application of this type of equipment is relatively simple.

The fundamental principle in heating a part to be brazed is to create an alternating magnetic field into which the part may be placed. In practice, the part is positioned in the center of a specially shaped coil and high frequency alternating current is applied for a predetermined time cycle. The coil is generally wound of small diameter copper tubing and roughly conforms to the shape of the part to be heated. The number of turns in the coil and the spacing between the turns and the part depends upon the size of the part, the rate of heating desired, and the electrical characteristics of the oscillator. With experience, it is usually easy to arrive at the proper coil by trial and error. Since high frequency currents on the order of 100 to 300 amp. are necessary in the coils to develop the required magnetic field, it is usually necessary to water-cool the coils.

To achieve high production in induction brazing operations, more than one part can be heated at a time by connecting a number of coils in series. With proper timing equipment, uniform heat over a number of parts can thus be achieved.

Preformed and preplaced silver solder strips or rings, and the design of suitable jigs to locate and hold the parts also greatly speed production and permit closer control over all variables in the brazing operation. Induction brazing equipment is admirably suited to production line operation and does not require skilled labor.

Design of Induction Brazed Joints

Any joint properly designed for brazing and of a shape such that an induction coil can economically be designed around it, can be successfully induction brazed. If possible, the joints should be designed to allow pre-assembly with the soldering or brazing alloy in position prior to placing the part in the jig or coil. Usually it is important that the

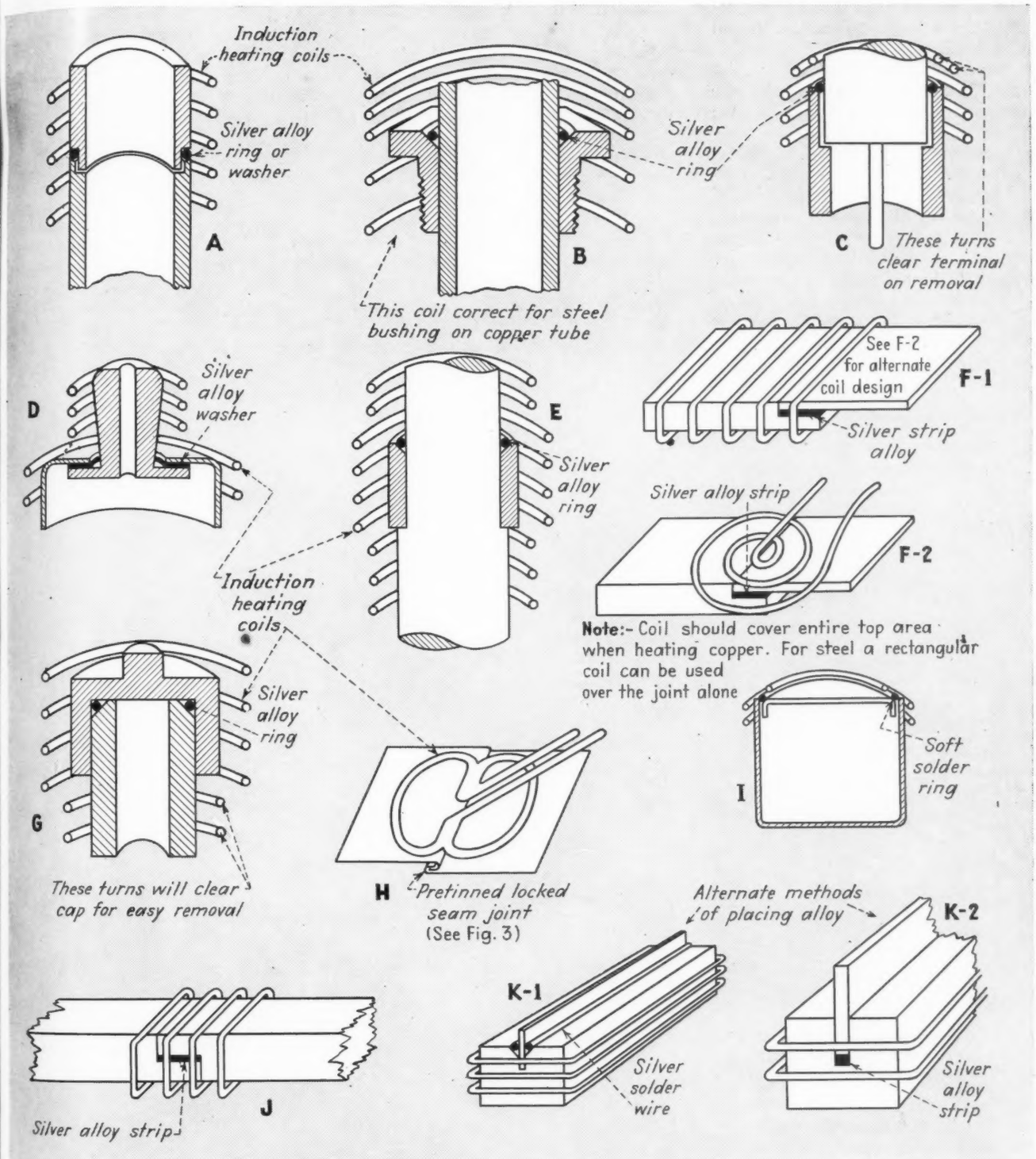


Fig. 1—Typical joints that are soldered or brazed by induction heating

alloy as well as the parts be thoroughly fluxed. Only where the surfaces are clean and the heating rapid can fluxing be eliminated. Fig. 1 shows several types of joints that have been successfully induction brazed. They include butt joints, lap joints, rolled seams, flanged joints, bushings, and others.

In designing any joint for brazing it is of course important that the clearances be correct. Maximum strength is realized with a clearance of approximately 1½ mils. Above 3 mils joint strength drops rapidly to that of the brazing alloy and the cost rises because of the excess of alloy used. Below 1 mil, difficulty is encountered in securing proper flow of alloy through the joint. Thus in joints such as those illustrated in sketch *B*, *E*, *H*, and *K* of Fig. 1, where the alloy must flow 2 in. or more and form an unbroken fillet at the open end, the clearance must be between 1 and 3 mils.

In a pressed joint such as sketches *D*, *F* and *J*, the surfaces should be reasonably close fitting and a clearance of ½ to 1 mil can be secured since no solder flow is required. In such joints a small fillet is unavoidable unless a groove is machined near the perimeter to receive excess solder. In joints where a press fit is inherent, such as rolled

seams in cans, the metal should be pretinned since proper solder flow cannot be secured.

When using preformed silver alloy rings, it is advisable to chamfer one part so as to direct the flow into the joint, thus allowing much greater tolerances in the dimension of the ring and contributing to ease of assembly.

When heating joints between thin and thick metal or between dissimilar metals, it is necessary to concentrate the magnetic flux on the section most difficult to heat, i.e., the one with the greatest mass or lowest electrical resistance. Thus both parts will be brought to brazing temperature simultaneously. In extreme instances all the heat can be concentrated on one part, the other being heated entirely by conduction.

Fig. 2—The bushing and terminal of a finned resistor are brazed in this fixture, which is attached to the power oscillator

The close control of temperature often makes it possible to complete a joint without affecting the finish on the parts. Silver plated parts have been brazed successfully without harming the plating, and tinplate can be soft soldered without oxidizing the surface. Sometimes it may be necessary to flux the surfaces near the joint to protect the metal where a bright surface is desired after brazing. However, even with copper, the oxide film is very light on account of the speed of heating.

Terminals on Calrod Units

In the assembly of Calrod resistance units, it is necessary to braze many different combinations of metals. Copper, nickel, silver, brass, steel and Nichrome are regularly used for different units depending on the application. The bushings are either brass or steel. Because the terminals which are brazed on the end of each unit contain a Mycalex insert, the heat must be carefully controlled to prevent cracking or melting of the Mycalex. While this job was previously brazed by gas torches, the application of vacuum tube oscillators resulted in speeding up the operation, consistently produced a more uniform joint, and eliminated the heat and fumes inherent in the use of gas.

The parts are assembled using preformed silver solder rings, fluxed and clipped in a fixture which automatically centers the joint in the heater coil. This fixture (Fig. 2) is adjustable to accommodate the various lengths and types of units. Settings of the timers and controls are tabulated for each size of unit and for each combination of metals used. Power is applied by a push-button and stopped by a timer when the part has reached the proper temperature. During the heating period, and while waiting for the solder to freeze, the operator assembles the next unit and the cycle is repeated. Heating cycles depend upon the size of the Calrod unit and material used, and vary from 5 sec. for small steel units to 50 sec. for larger copper-to-brass joints.

An unexpected advantage of this set-up was in reclaiming short lengths of tubing which were previously scrapped. An effort to braze these scrap pieces together by torch brazing did not succeed because the cost was high and the joints obtained were variable in strength, occasionally failing after the unit was completed, and resulting in considerable loss of time and material. Using induction heat, these pieces could be brazed rapidly and the joint obtained was uniform enough to eliminate failures during subsequent forming operations. This saving in material which otherwise would have been scrapped paid for the equipment in the first six months of operation.

Seams in Sheet Metal

One of the most difficult operations to perform satisfactorily is the continuous soldering of the longitudinal seam in a formed tube such as the ordinary tin can. In applying induction heat, it is necessary to concentrate the magnetic field on that area immediately adjacent to the seam, in order to avoid overheating of the thin metal near the joint. This operation has been successfully performed by the use of a small output transformer and a formed coil as shown in Fig. 3. These were made by Ajax Electrothermic Corporation. The advantages of this method are uniformity, localization of heat, speed, and virtual elimination of surface oxidation.

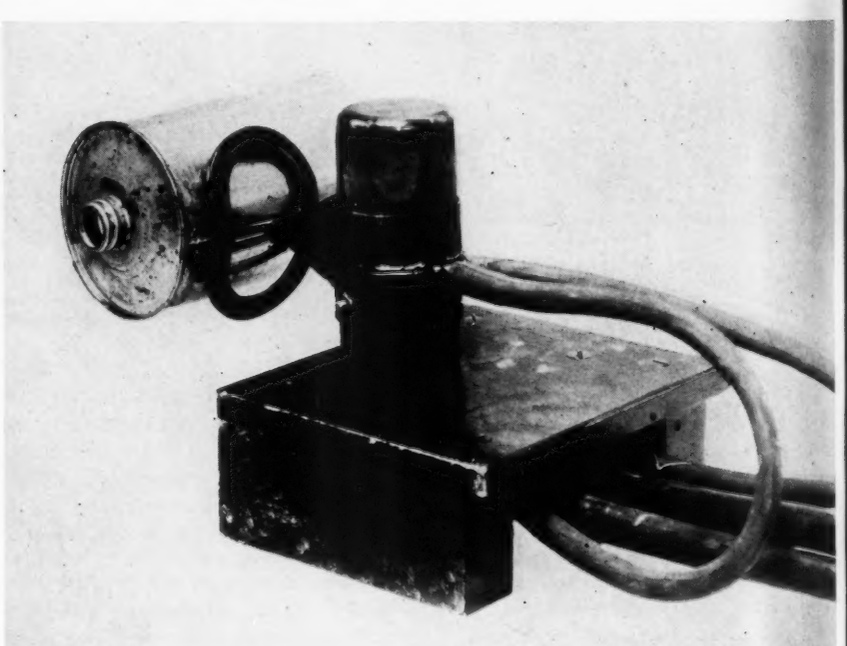


Fig. 3—Seams of cans are soldered with the aid of an output transformer and concentrator coil

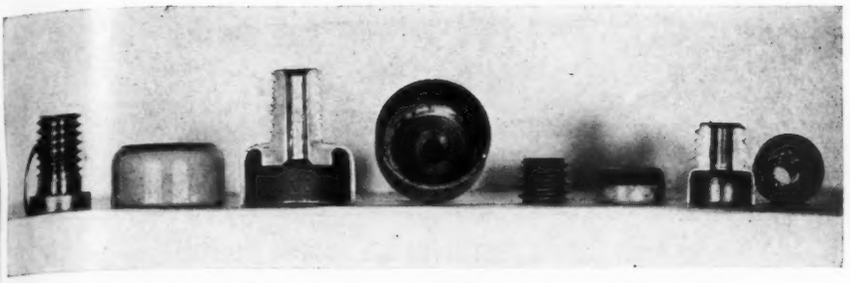


Fig. 4—Terminal bushing assemblies before and after brazing

Fig. 5—Multiple induction heating unit for soldering shells of oscillating-crystal holders

There are many applications where it is necessary to use airtight insulating bushings to permit electrical connections. In many cases a hollow ceramic bushing has been used, necessitating a metal-to-ceramic seal. To simplify this type of seal, a bushing has been developed in which the conductor and a metal flange are cast in a glass insulator. The flange can then be sealed to the container and a stronger, leakproof assembly results.

The copper stud used to terminate the electrical conductor is silver-brazed to an alloy cup which is coated with fused glass before casting in the bushing, two types of which are shown in Fig. 4. This part was previously made in two steps. First a silver solder washer was placed on the flange of the copper stud, fluxed, and the cup assembled over it. A number of assemblies were supported on pins in a tray and the whole placed in a muffle furnace until brazing temperature was reached.

After cooling, ground glass was applied to the rim of the cup and the parts returned to the muffle furnace until the glass fused on the metal. A 100-percent pressure test was necessary in order to detect faulty brazed joints and pinholes which were occasionally produced in the alloy cup when overheating took place.

By the use of induction heating a number of these operations were eliminated and others greatly shortened. The copper studs are now assembled to the cups with the fluxed silver solder washer in place and the glass applied to the rims. The parts are supported on pins in a locating block, each block holding six studs. These blocks are then placed in the heating fixture which locates an inductor coil around each stud. Power is applied and the brazing performed simultaneously with the fusing of the glass on the rim. A 20-sec. heat thoroughly fuses the glass. No test is required since the exact control of the temperature throughout the piece made possible by induction heat greatly reduces the possibility of faulty joints.

Soldering Crystal Units

In the manufacture of certain types of crystal units used for radio equipment, the crystal is mounted on a bracket inside a shell of the type commonly associated with metal radio receiver tubes. The bracket is mounted directly on the base or header and the shell assembled over it and soldered in place.

This soldering operation proved to be critical. If the header was overheated or heated too slowly, the heat was conducted up the bracket to the crystal, sometimes causing it to fracture. Also, any deposition of moisture or other foreign matter inside the shell affected the operation of the unit. This occasionally did not show up until the crystal had been in service.

Previously performed by gas ring burners, the above difficulties proved impossible to control. The products of combustion of the gas could not be kept out of the shell and overheating sometimes cracked the crystal.

By using a vacuum tube oscillator and pretinning the surfaces of the shell and header, the difficulties were largely overcome. The unit is placed in a fixture which locates it with respect to a two-turn inductor coil and a perforated air blast ring nozzle. Heat is applied for 3 sec. after which a cooling air blast operates for 10 sec. The entire sequence is timed automatically to assure uniform seals. During the heating cycle the operator twists the shell slightly to assure uniform distribution of the solder but does not touch the unit until the air is on to prevent "cold joints." The fixture shown in Fig. 5 is a new type that heats 6 units simultaneously. It automatically wipes the joints, thus removing the last possible source of non-uniform seals.

ADHESIVE APPLICATORS FOR H

APPLICATION of viscous liquid adhesives to fabrics, paper labels, wooden box heads, book binding, rubber shoe making, and in the making of paste board boxes, plywood, and many other purposes requires specially designed equipment for achieving satisfactory control of adhesives of different characteristics. The methods

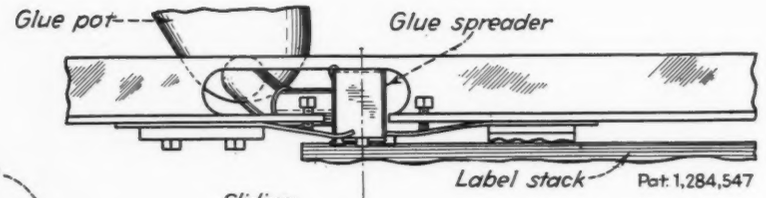
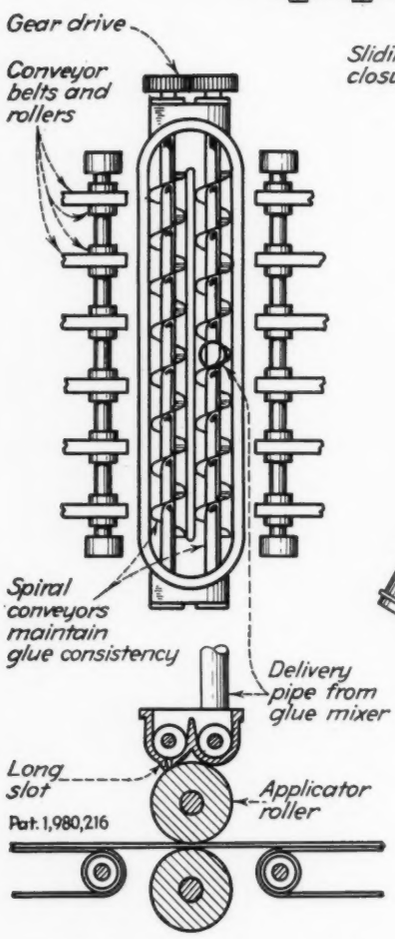


FIG. 1—*Gravity spreader has open bottom and grooved lip*



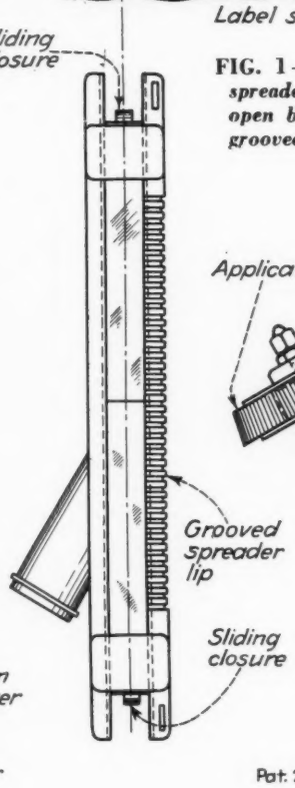


FIG. 2—*Spiral conveyors feed applicator roller by gravity*

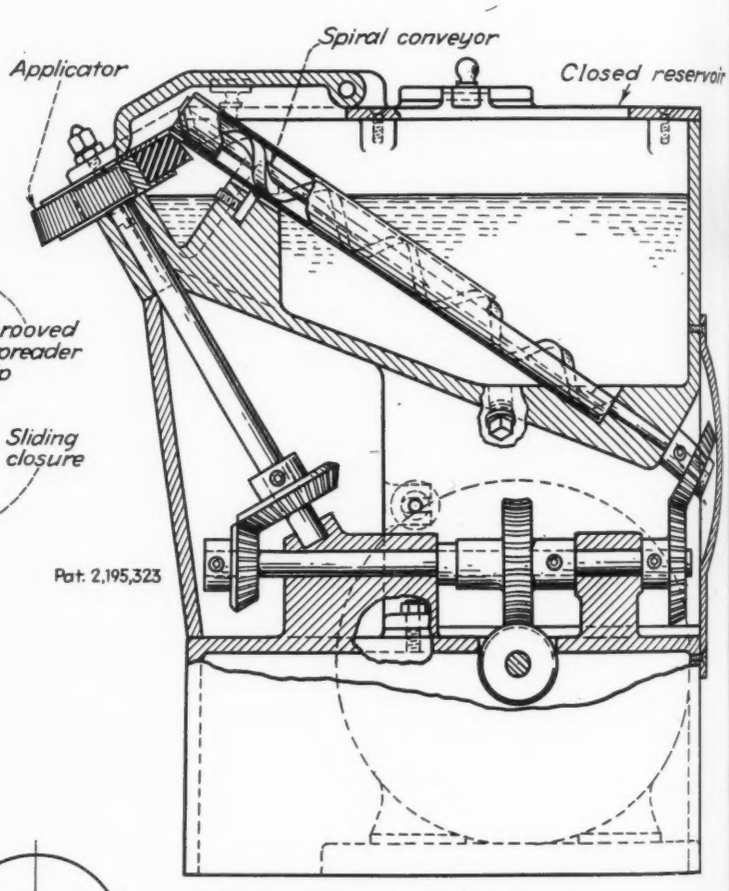


FIG. 3—*Applicator wheel fed by spiral conveyor*

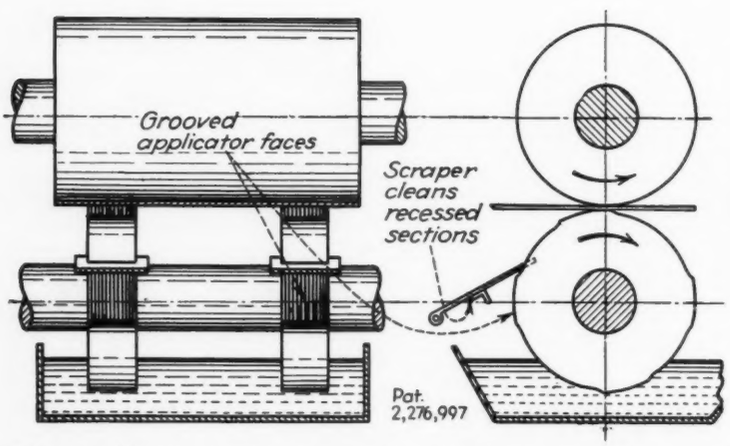


FIG. 4—*Adhesive pattern produced by raised faces on applicator roll*

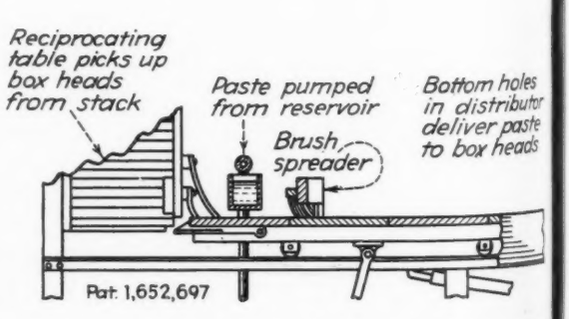

Reciprocating table picks up box heads from stack
Paste pumped from reservoir
Brush spreader
Bottom holes in distributor deliver paste to box heads
Pat. 1,652,697

FIG. 5—*Gravity spreader with flow from bottom holes*

FOR HIGH-SPEED MACHINES — I

shown here have been devised to incorporate the application of adhesives in production machines. Still other methods of application will be presented next month. In many instances these methods may be applicable for applying liquid finishes such as lacquers and paints also.

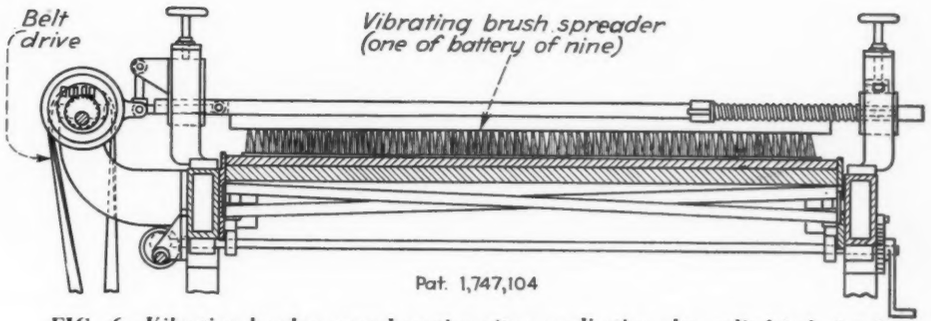


FIG. 6—*Vibrating brushes spread coating after application by cylindrical brush*

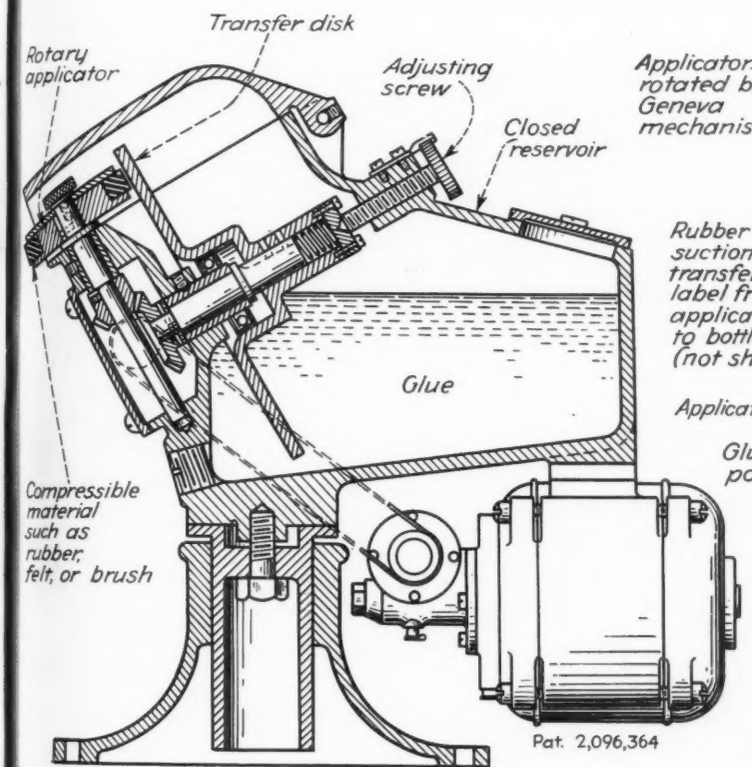


FIG. 7—*Applicator wheel fed by transfer disk*

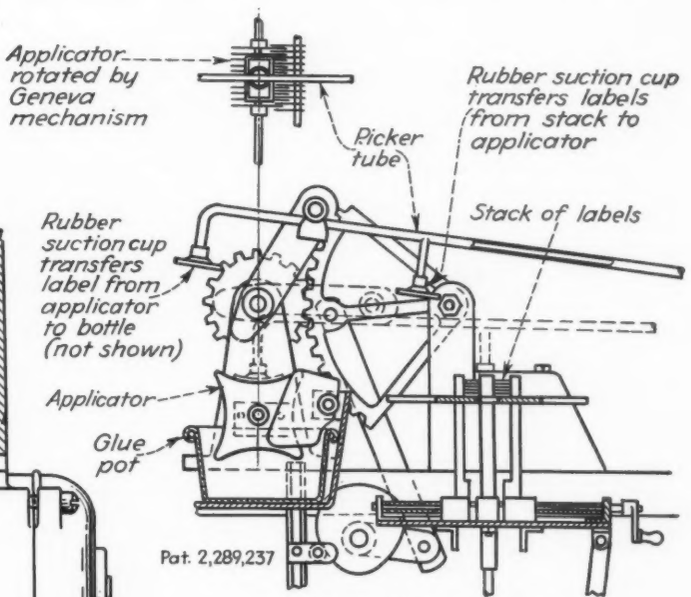

Applicator rotated by Geneva mechanism
Rubber suction cup transfers labels from stack to applicator
Picker tube
Stack of labels
Rubber suction cup transfers label from applicator to bottle (not shown)
Applicator
Glue pot
Pat. 2,289,237

FIG. 8—*Applicator surface consisting of series of plate edges rotated by Geneva mechanism in glue pot*

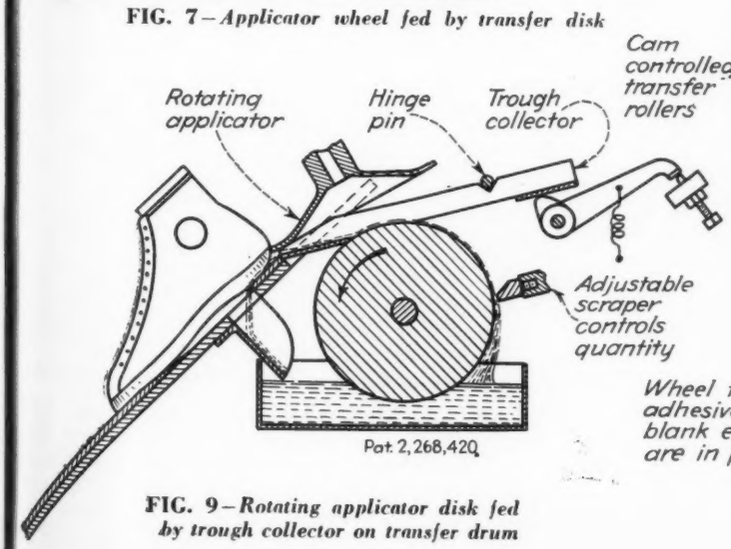


FIG. 9—*Rotating applicator disk fed by trough collector on transfer drum*

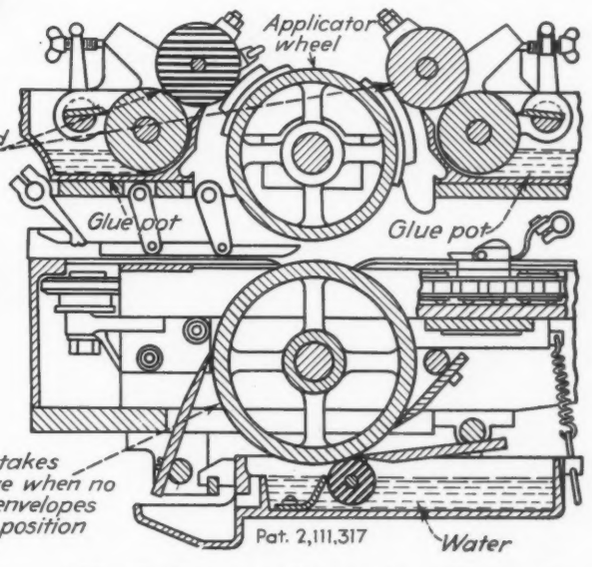


FIG. 10—*Cam controlled transfer rollers supply applicator wheel pads with two kinds of adhesive*

Dimensioning to Control Sizes And to Reduce Scrap Loss

SHERWOOD C. BLISS
Consulting Engineer

Wrong and right methods of specifying dimensional tolerances on parts having finished surfaces the dimensional relationship of which is not the result of one machining operation but of several operations. Simple rules are included for determining correct tooling dimensions.

ESSENTIALLY the problem which must be solved by the departments of a plant engaged in machining operations is to produce parts the dimensions and finish of which are within the tolerances specified by the product engineer, because if the material for the part has the correct physical properties it is obvious that, except for careless handling and abuse, the two factors which cause scrap are incorrect dimensions and finish.

Finish is usually a matter of a few ten-thousandths of an inch of the machined surfaces, consequently the major cause of scrap is incorrect dimensions.

There are plants where, despite a sincere effort to engage in war work, one would be surprised if he compared the amount of material exhibited in the scrap barrel in the lobby with the amount of critical materials scrapped in the shop. Much of this scrap loss can be eliminated by devoting a little study to the effect of tolerances upon the dimensions of the finished product.

For the purpose of this analysis it is convenient to separate dimensions into three classes:

1. Dimensions shown on the drawing of the product which can be termed "product dimensions." These are specified by the designer in order to control the dimensions of parts so that they will function properly in the assembled unit.

2. Dimensions specified by the tool designer for the machining operations on the part, which can be termed "Tooling Dimensions." These are determined by the tool designer to control the dimensions of the parts so that when completely machined they will be within the tolerances specified by the product dimensions.

3. Dimensions specified for the gages used for the machining operations. These dimensions are determined by the gage designer for the control of the tooling dimensions.

It is the custom of some companies to separate their gages into two classes called "work," and "inspection" gages. But this is practicable only in well disciplined organizations. In the average shop the discovery of differences between work and inspection gages usually leads to confusion. The use of two classes of gages and the resulting arguments can be avoided by sending all parts which do not pass the work gages to a salvage department where the questionable parts are reinspected with standard measuring instruments such as micrometers and height gages.

It has been the author's experience that, of the three classes of dimensions previously defined, errors are most often made in the tooling dimensions which control lengths, widths, and thicknesses, and are responsible for the greatest scrap loss. Tooling dimensions which control diameters usually cause little trouble.

An actual problem in dimension control, based upon a part typical of a small arms component, is illustrated in Figs. 1 to 6 inclusive. In all of these figures the tolerances are shown as bilateral in order to make the principles of control easier to understand.

The product dimensions controlling three surfaces on the part are shown in Fig. 1. As noted, this part is to be

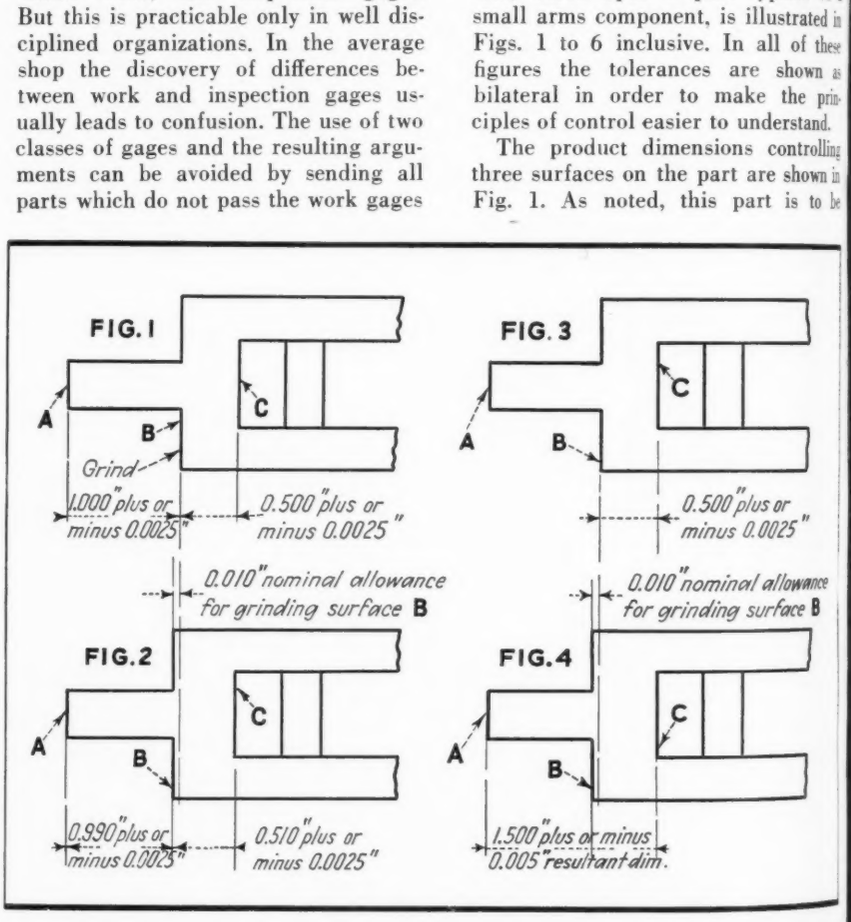


Fig. 1—Product dimension drawing which specifies the control required of the relationship of three surfaces. Fig. 2—Tooling dimension drawing which erroneously specifies machining operations on part before heat-treating. Fig. 3—Tooling dimension drawing which specifies grinding operation after heat-treatment. Fig. 4—Resultant dimensional relationship of the surfaces A and C after part has been machined in accordance with tooling dimension drawing

heat-treated after machining, also the surface *B* is to be ground after heat-treatment in order to obtain the required finish.

On receiving the product dimension drawing the tool designer made an arbitrary allowance of 0.010 in. for grinding the surface *B* after heat-treatment. He then issued tooling dimension drawings as shown in Figs. 2 and 3. Fig. 2 specified the tooling dimensions for machining the surfaces *A*, *B* and *C*, before heat-treating and grinding. Fig. 3 specified the tooling dimensions for the operation of grinding the surface *B* after the part has been heat-treated.

After the machining operations had been performed in strict accordance with the tooling dimension drawings, final inspection of the part disclosed that the tolerance in the distance from *A* to *B*, as specified on the product dimension drawing, had been exceeded. Consequently the part was sent to salvage.

A little study of the data here presented will show that the workman who, in compliance with the specifications of the tool engineer, machined the 0.990 in. dimension to a tolerance of plus or minus 0.0025 in., one of the first operations on the part, was making parts headed for the salvage department.

At first glance it would appear that the tolerance of plus or minus 0.0025 in. on each dimension was liberal and should cause no difficulty in the control of the dimensions of the finished part. The tool designer made an error when he specified the same tolerances for the machining operations performed before heat-treatment as are specified for the dimensions of the finished part. The tool designer lost sight of the fact that the product dimensions specify a tolerance of but plus or minus 0.0025 in. in the distance from *A* to *B*. Further consideration will show that to control the dimensions specified on the product dimension drawing, it is necessary to locate the part while the surface *B* is being ground either from surface *A* at the end of the part or from the surface *C* of the rectangular hole.

After machining, the dimensional relationship of the surfaces *A* and *C*, as shown by Fig. 4, was the resultant of the dimensions with tolerances specified in Figs. 2 and 3 for the tooling dimensions. It should be noted that the variable or tolerance in this resultant dimension is the algebraic sum of the tolerances on the two component dimensions. As a result there has been created a variable of plus or minus 0.005 in. in the distance between the surfaces *A* and *C* of the parts as machined. From this it is apparent that the dimensions specified for the grinding operation created a possible variable of plus or minus 0.0075 in. in the distance from *A* to *B* on the part. This is three times the tolerance specified on the product dimension drawing and was one reason for rejecting many parts.

Many other operations, not indicated in the illustrations, had been performed on the parts and the loss in time and material scrapped was considerable.

It might be argued that it was possible to grind more off of surface *B* or the end surface *A* in order to salvage the part. But, salvage operations are not production operations. Also, it might be said that it is usual to hold the overall length of parts such as the one shown within a specified tolerance, but if this had been done the tolerance on the overall length would make it still more difficult to salvage the parts.

The example here described is typical of many finished parts that have surfaces the dimensional relationship of which is not created directly by one machining operation but is the result of several operations, each of which creates a variable in the final dimension.

Experience with many examples of incorrect tooling dimensions which have caused high scrap losses has led to the formulation of two simple rules for determining correct tooling dimensions.

The first rule is: Whenever a final dimension is the result of several operations, the sum of the tolerances on each operation must not exceed the tolerance specified on the final dimension.

An example of how this rule applies to the part which has been discussed is as follows:

Inspection shows that either dimension *A* to *B*, or *B* to *C* will be the result of three operations, therefore, the sum of the tolerance on the three operations must not exceed plus or minus 0.0025 inches. The data enumerated in Table I will help to visualize the problem.

The second rule which is designed to reduce the number of intermediate operations required to produce a final dimension is: Whenever practicable select one surface for locating the part for all operations and refer all tooling dimensions to the surface selected.

The application of the second rule to the part which has been discussed is shown in Figs. 5 and 6. In this example it will be noted that the final dimension is the result of two, instead of three, operations. Also that the final dimension is the distance from *B* to *C*. Table II shows the arithmetical procedure. The increase in leeway on tolerance allowed

Table I—Application of First Rule

Operation	Dimension	Tolerance
Mill surface *B*	0.990	minus 0.0015
Broach surface *C*	0.510	plus 0.0015
First resultant	1.500	plus or minus 0.0015
Grind surface *B*	0.500	plus or minus 0.0010
Final dimension	1.000	plus or minus 0.0025

Table II—Application of Second Rule

Operation	Dimension	Tolerance
Broach surface *C*	1.500	plus or minus 0.0015
Grind surface *B*	1.000	plus or minus 0.0010
Final dimension	0.500	plus or minus 0.0025

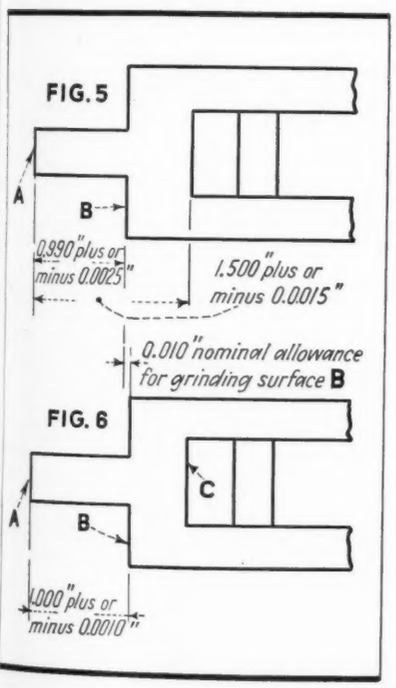


Fig. 5—Tooling dimension drawing with correct tolerances and method of locating the part for machining operations before heat-treatment. Fig. 6—Correct tooling dimension drawing for grinding operation after heat-treatment

for the setup man and operator on the broaching operation is apparent from the tabular data.

The first operation on a part is the most important. If dimensions for the first operation are not controlled correctly, trouble may not be discovered until the final inspection of the part, in which event all of the float in the department up to final inspection will have to be gone over in order to reduce the loss from scrap as much as possible.

The author has seen a great deal of scrap and many weeks of lost time caused by a lack of knowledge of the simple principles outlined in this article. It is with the hope that further waste will be avoided that the following is included to illustrate an example of the actual tolerances on tooling dimensions which caused scrap, and the revisions that were made to not only eliminated scrap but also to increase production.

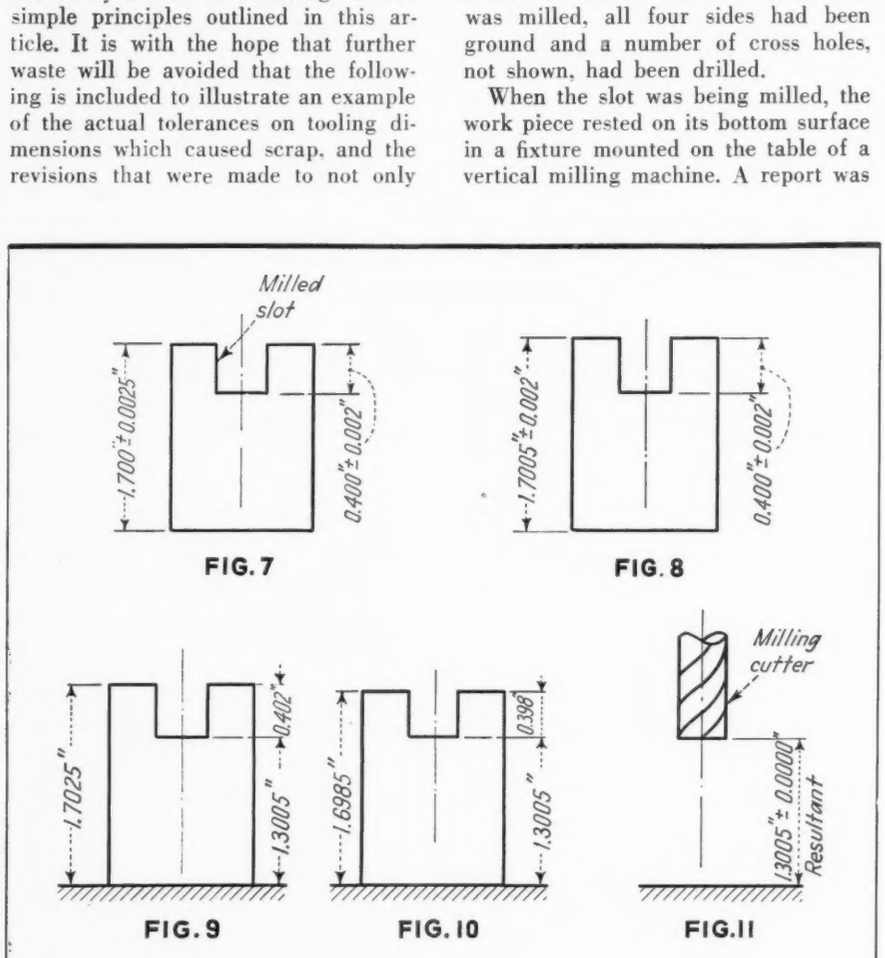
The operation, which was done on a vertical milling machine, was milling a rectangular slot in the top surface of a work piece. Fig. 7 shows the tolerances which were specified on the drawing of the product. The tolerances specified by the tool engineer are shown in Fig. 8. Gages were designed, made, and delivered to the machine shop for checking the work piece to the dimensions and tolerances shown by Fig. 8. Before the work piece was delivered to the machine where the slot was milled, all four sides had been ground and a number of cross holes, not shown, had been drilled.

When the slot was being milled, the work piece rested on its bottom surface in a fixture mounted on the table of a vertical milling machine. A report was received that it took from two and one-half to three hours for setting-up this job, also that the scrap was excessive. Figs. 9, 10, and 11 show why.

A piece which has been ground to the maximum height allowed by the tooling dimension and the work gage is shown in Fig. 9. The slot has been milled to the maximum allowable depth. In Fig. 10 the conditions have been reversed. Fig. 11 shows that, because of the variation in height of the pieces, from lot to lot, the set-up man had no leeway when setting the cutter in its relation to the surface upon which the piece rested in the fixture. It might be suggested that this piece should have been pumped up against a surface in the fixture which would locate it from its top surface. But that is not good tool design. The holes which had been drilled crosswise in the work piece also complicated the problem.

The solution of this problem is shown in Figs. 12, 13 and 14. A block for setting the cutter in relation to the locating surface on the fixture as shown by Fig. 12 was provided. The tolerance on the dimension for the height of the piece was changed as shown by Fig. 13. In this manner the resultant depth of the slots was held within the limits shown by Fig. 14, which agree with those specified on the product drawing.

It will be noted that the height dimension and tolerance shown by Fig. 13 will result in holding the height of the work piece towards the maximum height as specified on the drawing of the product. This is a good practice to follow when making parts for an outside concern. It eliminates the red tape and arguments which result in those cases where a part is a fraction of a ten-thousandth of an inch under the minimum dimension specified on the product drawing.



Figs. 7 to 11—Another example of tolerances on tooling dimensions which caused scrap. Figs. 12 to 14—The revisions that were made in the tolerances to not only eliminate scrap, but also to increase production

Specifying a Groove and Hole

Another example, illustrated by Figs. 15 to 19 inclusive, where scrap making tooling dimensions and gages were specified. The two machining operations involved were milling a shallow groove and drilling a hole in proper relationship to each other and to the end of the work piece. Fig. 15 shows the actual tolerances specified on the product drawing. Fig. 16 shows the tooling dimensions which were incorporated in the work gage used for the slot milling operation. In this figure and subsequent figures the letter *L* indicates the surface or center-line from which the work piece was located in the fixture.

The actual tolerance specified on the dimension for drilling the hole is shown

in Fig. 17, as well as the possible tolerance which would result in the distance from the center line of the hole to the face of the slot. Although the drill jig produced parts with holes located well within the tolerance specified for the dimension from the end of the piece, it must be apparent that the dimension from the hole to the face of the slot could not be held. With reference to the 1.750 in. plus or minus 0.003 in. dimension, the tool designer apparently considered that the tolerance on this dimension could be the sum of the tolerances on the component dimensions as shown on the drawing of the product.

The revised dimensions and changed locating points which were used to correct the trouble are shown in Figs. 18 and 19. This is an example where it was advisable to use separate locating points for each operation. This example does not tell the whole story as there were other factors such as the overall length of the work piece, which entered into the problem. It has been cited in order to explain some of the elementary principles of dimension control which can be applied to a number of manufactured parts.

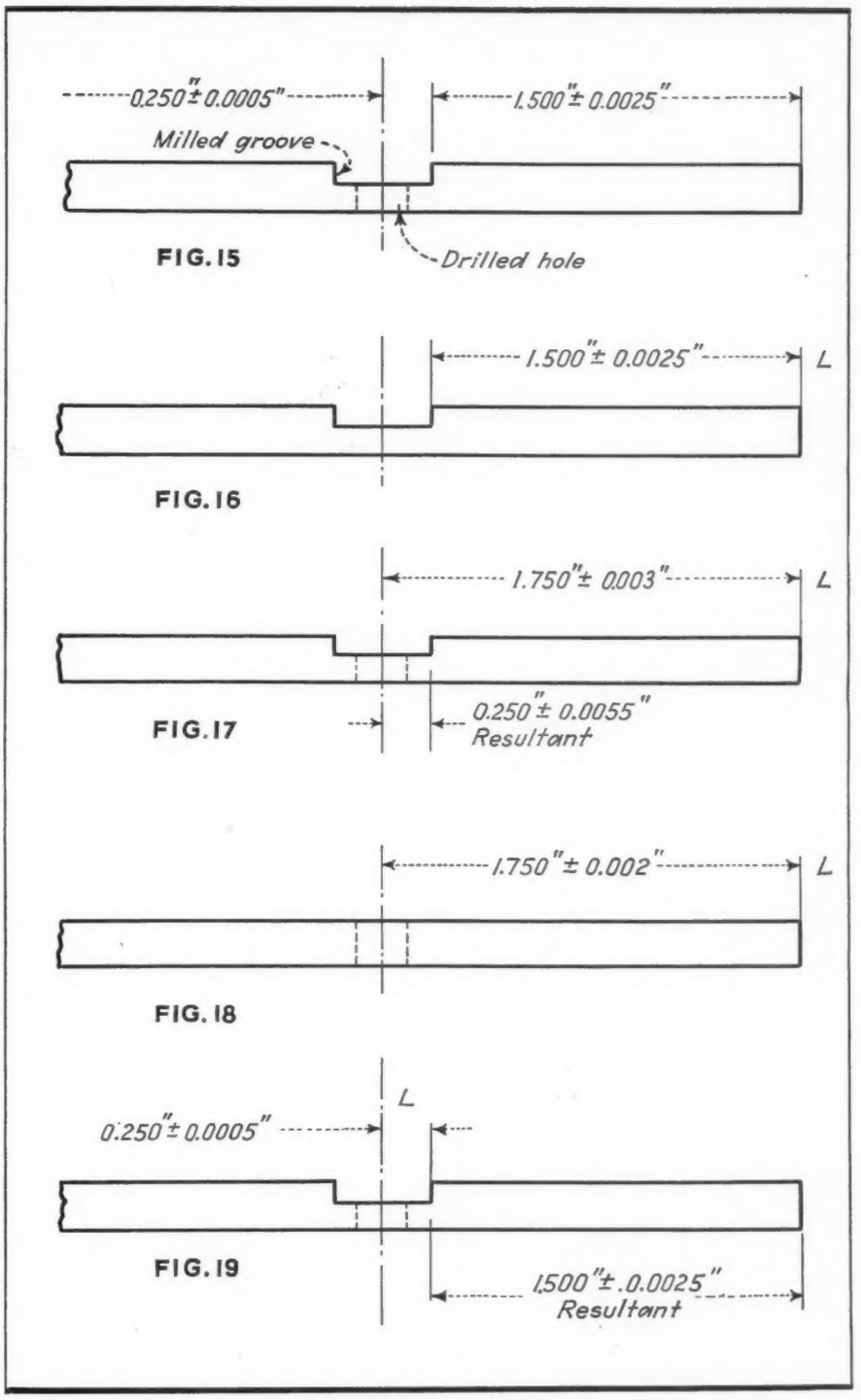
Responsibility for Waste

It must be admitted that the product designer shared equal responsibility with the tool engineer for the waste of time, gages, tools, and critical materials experienced on the job from which these examples have been selected.

Product dimensions were referred to either end, either side, and either the top or bottom of many parts. Had they been referred to but one end, or side, and say the bottom surface, much time and expense would have been saved.

A great deal of trouble can be traced to a pernicious note which appears on many drawings. The note states that "The tolerance on dimensions unless otherwise specified", is to be within certain limits. The limits are usually plus or minus 0.005 in., or plus or minus 0.010 in., if they refer to machined dimensions. There is never anything in between these figures.

Some concerns interpret this note to mean that the tolerance on the location of any surface when not otherwise specified can be the cumulative sum of the tolerances on the dimensions which form its components. Other concerns interpret the note to mean that the tolerance specified is the maximum to be allowed on any dimension not otherwise controlled and apply this interpretation to dimensions which are the resultant of several machining operations. This last interpretation is the most logical. There are many examples, especially in cylinders which have stepped diameters on the interior as well as the exterior, where the first interpretation would lead to critically thin or weak walls at certain shoulders. It is the opinion of the author that every dimension should have its tolerance specified. If such a practice is followed many erroneous interpretations will be avoided.



Figs. 15 to 17—Scrap making tooling dimensions and gages are specified for this part in which two machining operations are involved. Figs. 18 and 19—Revised dimensions and changed locating points which were used to correct the trouble

The product designer who understands the rudiments of machining operations, the elements of dimension control, and the effect of cumulative tolerances, upon production costs and scrap, can prevent a great deal of waste, by exercising some analytical forethought and attention to the sequence of machining operations and their respective locating points or surfaces.

Spring Material Substitutes Have Unconsidered Qualities

W. W. BOYD

Substitution of other materials for standard spring steels calls for re-examination of spring materials that served in the past, consideration of new resilient materials, and evaluation of other basic qualities in spring materials in addition to resilience. Means for producing ferrous spring materials and ways for using wood, plastic, and even glass are suggested here for at least temporary substitutes.

UNDER present wartime restrictions the customary ferrous and non-ferrous metal spring materials are difficult to obtain. Alloying elements, because of their scarcity, are reserved for military applications. It is, therefore, necessary to explore other fields for materials to replace those most familiar to industry. A search for equivalent spring materials discloses some interesting facts on the experience of the past and on new materials. While most substitutes are inferior to spring steel, they may be practical for many service conditions.

Ferrous metal springs are usually made of high carbon steels and alloy steels containing small percentages of manganese, silicon, chromium, titanium, vanadium, and other elements in various combinations. Hard rolled steel sheets are also used. The usual non-ferrous metals are hard rolled copper, brass, aluminum, zinc, and their numerous alloys.

Ferrous metals once were expensive. Wrought iron was made by the puddling process, then forged many times until the iron was thoroughly refined. Since charcoal was the fuel used in the process very little sulphur and phosphorus were absorbed, but the affinity of red hot iron for carbon changed the soft, malleable wrought iron to the harder more rigid steel.

Naturally, this material was not uniform in composition and proved to be unreliable in springs. Because of this uncertainty, Huntsman developed the crucible process, and Sheffield, England, became famous as a center for high-grade steels. In the crucible process small pieces of wrought iron were placed in intimate contact with powdered charcoal, the whole being contained within a clay crucible having a closely fitting cover which was sealed with clay to reduce oxidation during heat-treatment.

The sealed crucible was placed in a furnace where it remained for a period of time that varied with the size of the iron bars and the amount of absorbed carbon desired in the product. To obtain larger carbon steel bars, these small carbonized pieces were piled, then heated to a welding temperature and drawn to commercial sizes.

About the time this process was developed, the frequent breaking of watch springs was demanding attention. In fact the search for a dependable spring steel was responsible for the discovery of the crucible process. Present methods for cyaniding, gas carbonizing, pack hardening, and others were derived from the crucible process. If it is necessary to use steel, then a good grade of low or medium carbon steel can be carbonized by these production methods and excellent results may be expected. Hardening of sections over ¼ in. minimum dimension take too long by these methods but may be accomplished by use of oil, water or brine.

Soft iron strips and wire can be carbonized quickly and utilized as springs. If fairly large helical springs are required, they can be machined from low carbon bar stock by drilling a hole the size of the inside diameter of the spring, turning the outside to the desired diameter, then cutting a helix through the wall with a parting tool or a milling cutter. If tubing is available, springs may be cut in a thread miller. In this method of manufacture, square and rectangular sections are more economical, but by proper tooling, round and elliptical shapes may be approximated. Carbonizing and hardening are then employed to develop desired spring quality. If a dense, hard cast iron is available, springs may be turned from bars of this material and good service obtained.

Wooden Springs

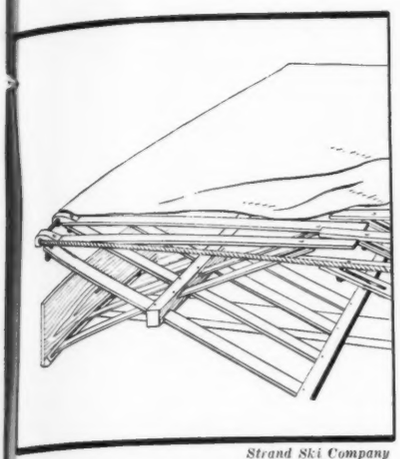
Before the advent of steel springs the use of hickory and ash was common. Many farm and road vehicles such as the buckboard with its platform of thin wide strips of resilient wood, had wooden springs. Early railroad rolling stock had wooden semi- and full-elliptical springs. Use of many sorts of wooden springs on industrial applications, such as power hammers, certain paper mill machinery, shanks of golf clubs, archer's bows, etc., is not unusual.

Naturally dried lumber, particularly the strongest and densest, splits and checks. This decreases its strength and general usefulness, but this tendency can be overcome by the use of several kinds of chemical preservatives. Elimination of checks in timbers improves horizontal shear strength.

Among the best-known water soluble preservatives are zinc chloride, chromated zinc chloride, and sodium fluoride. If high electrical insulation is required, chemicals like urea or invert sugar, which do not affect electrical conductivity, are preferable to sodium chloride and mon-ammonium phosphate. Common salt, sodium chloride, because it is hygroscopic, causes the wood to become damp in humid atmospheres. This chemical is corrosive also, but its use does prevent checking. Impregnating wood with urea, phenolic resins, etc., has prevented checking and improved homogeneity to such an extent that wood can be used as a spring material.

Plastic Springs

Latest improvements in laminated phenolic plastics have improved their toughness and resistance to impact to such an extent that their use as a substitute for metal springs can be given serious consideration. Special varieties of plastics can be developed for partic-

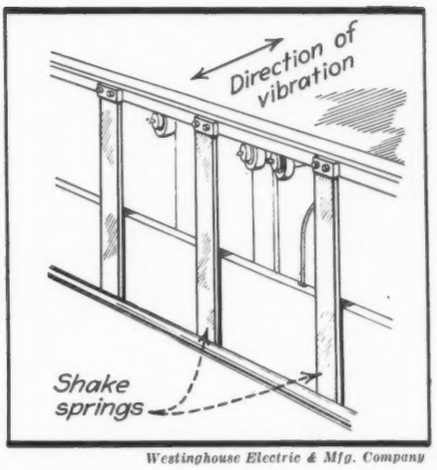


Strand Ski Company

Resiliency and wear of steel coil springs is claimed for this design of furniture springs in hickory. Center backbone binds the slats into a unit with four spring-board actions independent of each other

Heywood-Wakefield Company

Birch elements in these chair springs are formed in a steam press. Ends are wired through drilled holes. Spacers are plastic fiber positioned by wire around bent wood elements and through the fibre

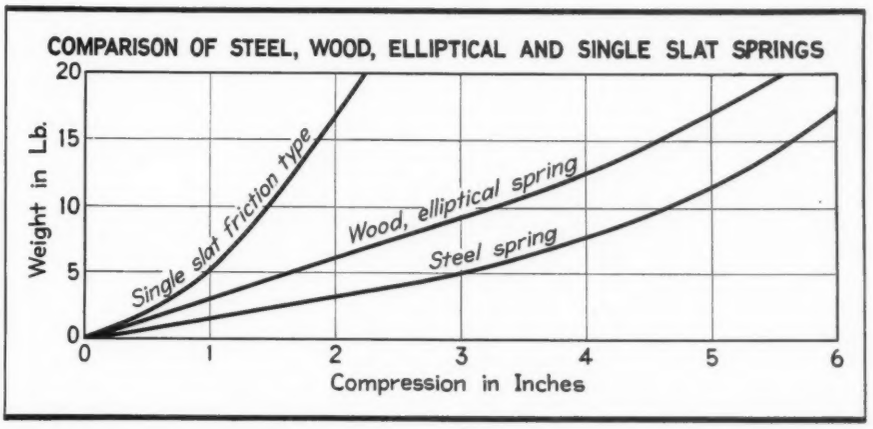


Westinghouse Electric & Mfg. Company

Shake springs for the table of a paper making machine proved better in laminated Micarta than metal or wood. A series of these springs support the vibrating bed of the machine on each side

ular requirements by varying composition and materials used as a base.

Tensile strength varies from 5,000 to 12,000 lb. per sq. in. Flexural strength ranges from 6,300 to 48,000 lb. per sq. in. and compressive strength may be 22,000 to 30,000 lb. per sq. in. The modulus of elasticity shows a spread of from 400,000 to 1,700,000 lb. per sq. in. Shock resistance is also worth investigation because the observed values are as low as 0.23 ft. lb. to as high as 2.7 ft. lb. (Izod), or 2.88 to 34 lb. per sq. in. Because of this broad range of physical properties, complete data should be obtained before a definite selection of material is made.



A surprisingly close approach to the resiliency of steel springs is made by Heywood-Wakefield's bent wood elements

Glass Springs

Glass is rarely regarded as a spring material but it is a hard and brittle substance that has surprising elastic properties, as evidenced by the deformation of large plate glass show windows under the pressure of gusts of wind and the elastic curve assumed when a sheet is lifted at one edge. No signs of fatigue appear over long periods of time. Advantage of this flexibility is obtained in the recent development of glass cloth and other insulating materials, and many uses in prospect.

Strips of glass can be used as cantilever springs or made up into elliptical springs. Helical springs are made of round filaments of glass of considerable size (see PRODUCT ENGINEERING, May 1940, p. 197). Its high insulating qualities make it valuable for electrical instrument springs.

Physical properties of glass are: maximum working stress 1,000 to 2,500 lb. per sq. in. (depending upon size and shape of the part), modulus of elasticity 10,000,000 lb. per sq. in., modulus of shear (torsion), 3,400,000 lb. per sq. in. and Poisson's ratio 0.22. The nature of glass, its brittleness, does not give a yield point; it just breaks. Polished plate glass has an ultimate tensile strength of 6,500 lb. per sq. in. For engineering calculations, a working stress of 2,000 lb. per sq. in. can be used for tempered glass.

Lately, a shock resistant, tempered plate glass has been developed, which has an ultimate tensile strength of 29,500 lb. per sq. in. Tempered glass is 4½ times as strong as annealed glass under static loading and will deflect four times as far before breakage. This tempered plate glass has excellent elastic properties and has been used for exhibition diving boards, glass doors, etc. The non-crystalline structure of glass probably accounts for the notable absence of fatigue when subject to repeated loading within design limits.

Because of the low strength of these non-metallic substances, larger sections are required. While some sacrifices are, of course, inevitable in making substitutions for high grade steel springs, it is also true that in many applications lower strength materials can be used with satisfactory results. Furthermore, the necessity to try out elastic materials that served in the past and new materials with elastic properties, such as plastics and glass, will steer engineering thinking along lines of basic qualities such as elasticity, frequency of vibration and other properties of value in springs, rather than to remain in the rut of fitting a standard type spring to space and strength requirements alone. Means for altering the straight line relation between deflection and force exerted, as was done to make the torsional rod spring practical for buses and trucks (see PRODUCT ENGINEERING, Dec. 1942, p. 710) may also have possibilities in designing other types of springs.

Industry and Societies

NEWS · READER LETTERS · MEETINGS

Ordnance Department Displays Military Secrets

TANKS, GUNS and other war matériel, some of it too secret to be mentioned, were displayed by the U. S. Army Ordnance Department to newspaper men and radio commentators during a recent visit of the group to the Aberdeen Proving Ground. Major-General Levin H. Campbell, Jr., chief of ordnance, was in charge.

One of the highlights of the visit was the display of a new secret weapon that is being used by infantrymen and which may make obsolete what is considered today one of the principal weapons of war. However, nothing more can be said about this weapon, due to military secrecy.

Observations made by General Campbell to the group were to the effect that no artillery in the world is now equal to the United States artillery, the medium-size M-4 tanks and the light General Stuart tanks cannot be matched by any other tank in the battlefield, the advance in the fire-control elements of artillery has exceeded the most practical expectations of military authority, and the quality of ammunition used by the Army far exceeds anything that the enemy can show.

One important point which was brought out was that the design of the German 88-mm. gun is actually not as good as some American weapons, including the 105-mm. gun. The reason for the publicity given to this German gun was the results achieved by unusual use of the gun by General Rommel in Africa, rather than the design of the gun itself.

General Campbell also said that the United States was meeting the Germans in the field of finding substitutes for indispensable articles. He cited as an example how the Army has cut the amount of nickel used in the construction of medium tanks from 630 lb. to 34 pounds.

A new semi-automatic carbine, recently standardized by the Ordnance Department, was also displayed. This weapon is capable of accurate fire up to 500 yd. and General Campbell said that it will supplant the revolver and automatic pistol for company and platoon commanders.

Aluminum Forging Output Increased 25 Times

PRODUCTION OF ALUMINUM FORGINGS is at a rate 25 times that of 1938, according to an announcement by Aluminum Company of America. This expansion is regarded as "second to none" in the aluminum field.

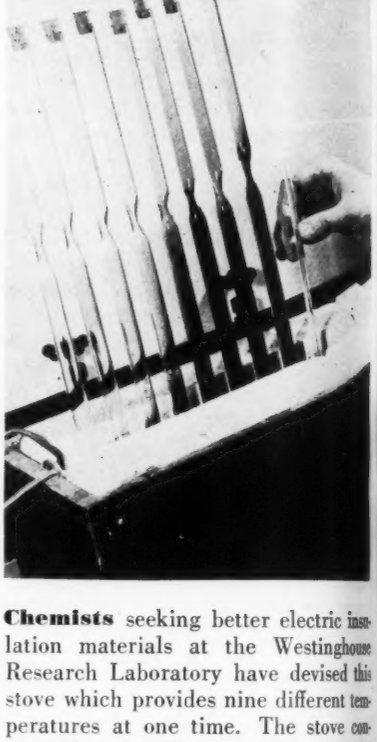
Aluminum forgings are being used to a great extent in the construction of war planes. Fighter planes require as many as 150 different types of forgings and big bombers may have as many as 300 different types. Most familiar of these types is propeller blades. Pistons and crankcases are also important items.

Sodium Lamps Give Fine Inspection Lighting

SODIUM LAMPS are being used in several war plants to give inspectors maximum possible light for locating minute surface defects.

These lamps are especially efficient, according to H. A. Breeding, of the General Electric Illuminating Laboratory, because they are monochromatic. Since the eye focuses only one color band at a time, multiple colors in a beam tend to fog the image, and under such conditions, microscopic defects may be lost. Sodium light is very near the point of maximum eye sensitivity in the spectrum.

For best results, inspectors mount the light source comparatively high, particularly when there is small contrast between flaw and surface. When searching for cracks or blow holes, the inspection surface should be treated with a light-absorbing or light-reflecting dye, and in all cases, sunlight should be excluded as much as possible.



Chemists seeking better electric insulation materials at the Westinghouse Research Laboratory have devised this stove which provides nine different temperatures at one time. The stove consists of an iron bar, heated at one end and cooled at the other. Holes drilled into the bar at equal intervals record an equal difference in temperature. Insulation tougheners are cooked in test tubes in this stove to determine the temperatures at which insulation is weakened and made brittle.

Brassert Process May Solve Sponge Iron Problem

APPROPRIATION by the War Production Board of $450,000 for the Republic Steel Company to build a 100-ton a day

plant for the production of sponge iron by the Brassert process, indicates that serious consideration is being given this material to help overcome one of the big problems in steel production. This process, developed by Herman A. Brassert, a metallurgist, consists of first crushing the ore to a powder. Next, the metal bearing component is separated from the impurities by gravity, flotation, magnetic or other approved means. The powdered ore is then fed to a Herresoff furnace, where it is reduced to briquettes of approximately pure iron.

The object of this process, at this time, is to enable foundrymen to produce a metal of consistent quality and to relieve the necessity for high-grade scrap. Brassert melting stock can be mixed with other metals and minerals to obtain high quality steel. Since the melting stock is practically pure, a steady supply of constant composition material can be relied upon, eliminating the worry over possible foreign substances which may creep into the steel manufacturing process when scrap of unknown origin is used.

Curtiss-Wright Building $2,100,000 Wind Tunnel

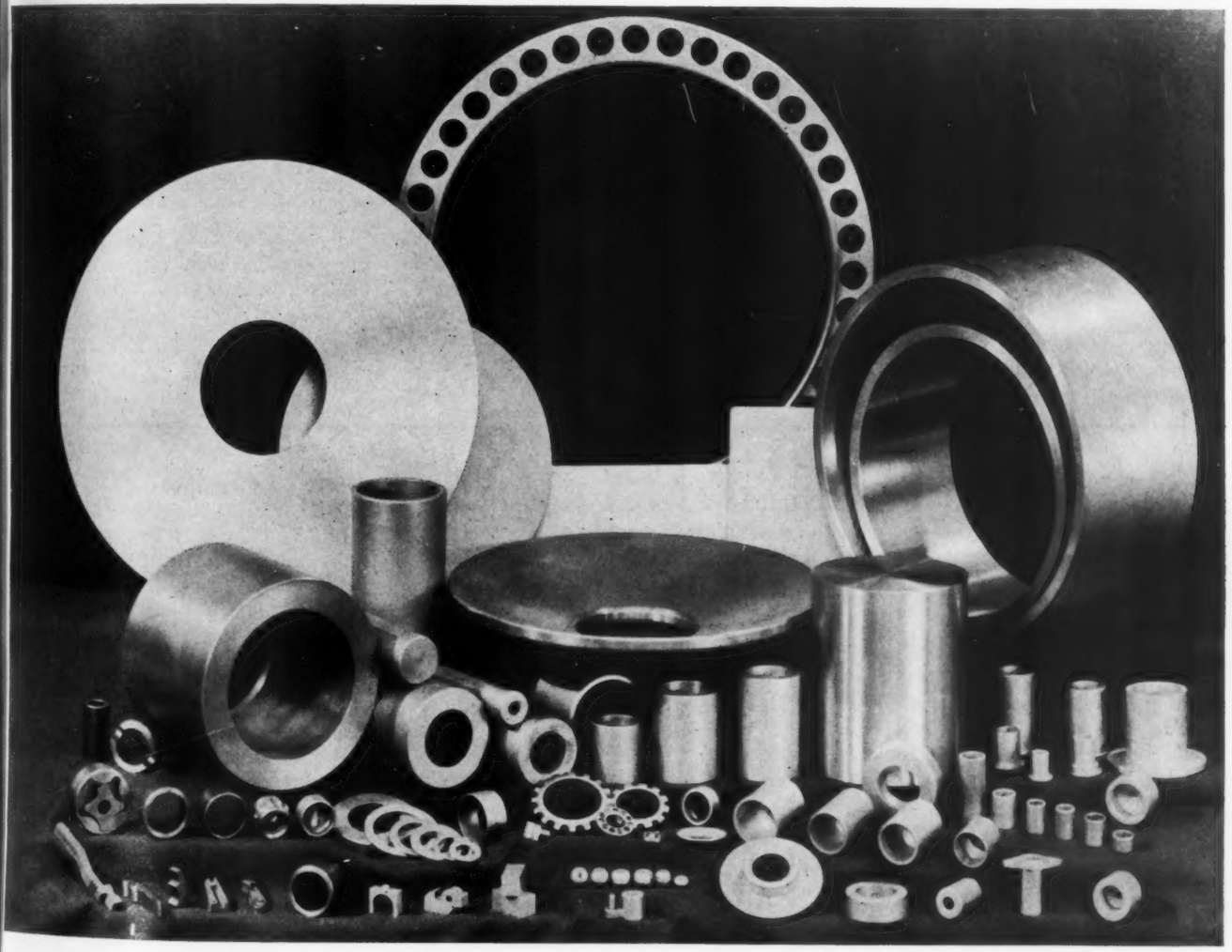
CONSTRUCTION of a $2,100,000 wind tunnel is being rushed by the Curtiss-Wright Corporation at an airplane division. The tunnel is designed to create an artificial wind velocity of 700 m.p.h. It will be available to other aircraft manufacturers for testing. An altitude chamber will accommodate singe-place fuselages and will be able to reproduce actual dive and climb conditions.

Motion Picture Explains Mechanical Drawings

OF INTEREST to groups studying mechanical drawing, including secondary and vocational schools, colleges and apprentice classes, is a sound motion picture titled "Behind the Shop Drawing," being distributed by the Jam Handy Organization, Detroit, Mich. The picture is elementary in character, designed to present the broad principles

Powdered Metal Parts Save Strategic Metals

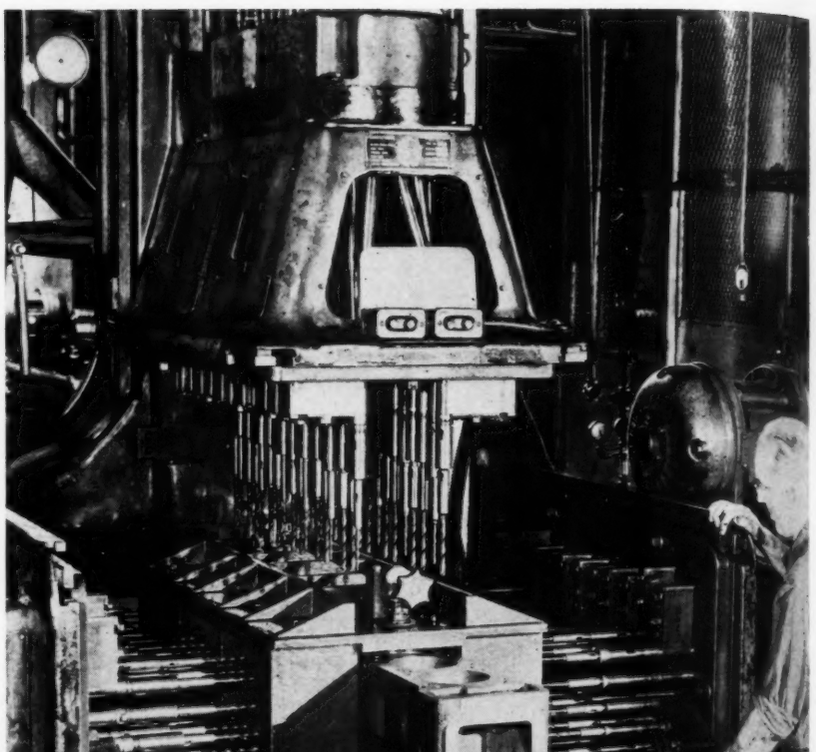
DIVERSIFICATION AND EXPANSION in the design and production of parts made from powdered metal will save millions of man-hours and thousands of tons of strategic metals in 1943. On one Chrysler-built weapon using 106 parts made by the powdered metal method, 1943 production will show a saving of 4,000,000 man-hours and 1,250,000 lb. of hard-to-get metal. In recent innovations developed by the Amplex Division of Chrysler Corporation, iron base parts have replaced copper, bronze and other metals and alloys. Powdered iron parts can be made either in the oil impregnated type or as a dense structure where tensile strength, elongation and hardness are required.



of the subject and to save the time of the instructor for more detailed training. The importance of shop drawings is first visualized as the narrator explains perspective drawings. Next, the method of making a shop drawing is covered, step by step, using animated lines, arrows and translucent paper so that the reason for each line can be easily understood. Drawings of more complicated objects are also explained, as are dimensions, figures and lines. The latter part of the picture shows how blueprints are made.

100,000 Hr. Creep Test Given Alloy Steel Rods

HIGH TEMPERATURE CREEP TESTS, lasting 100,000 hours, the longest on record, of four 4-ft. rods of nickel-chrome-moly steel (SAE 4340) 0.505 in. in diameter, have been completed at the Schenectady Works of the General Electric Company. The four specimen rods were imprisoned in a thermostatically controlled electric furnace and represented one of the best known alloy steels for high-strength forgings and bolts required in the manufacture of steam turbines. The test was made to determine what stresses could be used at temperatures where all materials are plastic, without causing deformation larger than the minute values tolerable in high-speed machines. A 12 in. portion at the center of each rod constituted the test area. Temperature of the furnace was maintained at 842 deg. F., and the four rods were subjected to constant stresses of 13,000, 17,000, 21,000 and 25,000 lb. per sq.in., respectively. The No. 1 rod, with the lowest stress, stretched 0.928 mils per inch of length. Extensions of the others were 1.398, 2.729, and 4.166 mils per inch.



Output of Hudson Invader aircraft engine cylinder blocks has been tremendously increased through the use of three-way multiple drills such as shown here. Simultaneously, more than 100 holes on three sides are drilled. A companion machine taps the holes in the same manner. More blocks are handled in one hour than were produced in a day under former production methods whereby these holes were drilled and tapped individually.

Discussions and Comments from Readers

LARGE DRAFT ANGLES AND FILLETS FOR FORGINGS ARE DENOUNCED

To the Editor:

As most drop forgings are sold by the pound, it logically follows that the more pounds on the forging, the higher the price received and the easier the forging is to produce. That is, profits on the forgings are increased from two sources. On the other hand, these oversize forgings cost more for material, more to machine, possess inferior physical qualities and, while reducing reliability, add to the total cost of the mechanism in which the forgings are embodied, hence, my feeling of the colossal disservice which is rendered to all parties concerned by the publication of articles that advocate forgings with large draft angles and large fillets.

We advocate the use of modern drop-forging equipment with high anvil to falling weight ratios to give maximum deformation per blow; rigid structures to insure precision of die matching; and a cylinder design which imparts a ram velocity designed to make draft angles as small as 1 deg. practicable and prolong die life by making the impact period extremely short and snappy. The results are low cost, precision forgings with small draft angles requiring minimum machining and the overall result is a material reduction in the overall cost of the machinery, of which the forgings form a part.

—R. E. W. HARRISON
Chambersburg Engineering Co.

[EDITOR'S NOTE: The writer, we believe, is substantially correct in most of his viewpoints of what constitutes good forgings and good forging practice. However he has not placed proper emphasis on present conditions, which make it imperative to design forgings that are, as he puts it, easier to produce. For one thing, maximum die life is essential today. It does not follow, either, that larger drafts and fillets re-

sult in inferior forgings. To the contrary, they are usually better in strength and reliability.]

NOMOGRAM FOR RECTANGULAR MOMENTS AND SECTION MODULI IS APPROVED

To the Editor:

I wish to thank you for your splendid cooperation in regard to my suggestion for an alignment chart (PRODUCT ENGINEERING, Jan., 1942, pp. 61 and 62) for rectangular moments of inertia and section moduli as per formulas on page 94 of the *Handbook of Mechanical Design*. Everyone on our staff who saw the chart agrees that it is a well-balanced, practical and useful chart. The range of the variables is okey.

In the third paragraph on page 61, $Ah^3/36$ should read $bh^3/36$.

I would be very much interested in nomograms for determining moment of inertia, section modulus and radius of gyration of a rectangular section at any angle. The machine designer would certainly find it of great value.

—N. F. SNYDER
Tool Engineering Dept.
General Motors Institute

[EDITOR'S NOTE: Charts in line with Mr. Snyder's suggestion were already being prepared when his letter was received. They will appear shortly in a forthcoming issue.]

Activities Among Technical Societies

A.S.A. ANNOUNCES INTER-AMERICAN PROGRAM

Cooperation on industrial and engineering standards is the purpose of a program for promoting trade and industrial development in the Americas that has just been launched by the American Standards Association. Latin American countries have already shown a great deal of interest in North American standards and have asked the A.S.A. to supply further information.

Under the program the A.S.A. will exchange technical data in the development and use of standards with the other American republics, give them information on the standardization work being done in the United States and provide them with Spanish and Portuguese translations of standards which would be particularly valuable in developing their industries. A prime object of the program is to provide so thorough an interchange of technical data and information that all of the countries of the Western Hemisphere will have standards that are as nearly universal as possible.

Full-fledged national standardizing bodies are now in operation in Argentina, Brazil and Uruguay. In other countries there are government departments and engineering societies doing similar work. Furthermore, there is a South American committee to further standardization work in the ten South American Republics.

E. H. ARMSTRONG AWARDED EDISON MEDAL FOR 1942

Dr. Edward H. Armstrong, professor of electrical engineering at Columbia University, was to be awarded the Edison Medal for 1942 on January 27 at the National Technical Meeting of the American Institute of Electrical Engineers. The award was presented "for distinguished contributions to the art of electric communication, notably the regenerative circuit, the superheterodyne and frequency modulation."

PERKIN MEDAL PRESENTED TO R. E. WILSON

Dr. Robert E. Wilson, president of the Pan American Petroleum and Transport Company, was presented with the Perkin medal for 1942 on January 8 by the American Section of the Society of Chemical Industry at a joint meeting with the American Chemical Society, American Institute of Chemical Engineers, Electrochemical Society and the Société de Chemie Industriele. The medal was awarded to Dr. Wilson in recognition of his research studies on such varied subjects as flow of liquids, oiliness, corrosion, motor fuel volatility, clay and glue plasticity, and humidity, and in recognition of his industrial contribution to the use of tetraethyl lead, petroleum hydrocarbon cracking and adoption of chemical engineering principles by the oil industry.

SIKORSKY, WELLS HONORED BY AERONAUTICAL INSTITUTE

Igor I. Sikorsky, engineering manager of the Vought-Sikorsky Aircraft Division of United Aircraft Corporation, has been elected an honorary fellow of the Institute of Aeronautical Sciences and will receive the Albert Reed Award for 1942. Honorary fellowship is the institute's highest honor and is conferred in recognition of preeminence in aeronautics. The Reed award will be presented to Mr. Sikorsky with the citation "for the creation and reduction to successful practice of a helicopter of superior controllability."

Edwards C. Wells, of the Boeing Aircraft Company, is to receive the Lawrence Sperry award for 1942 for "outstanding contribution to the art of airplane design with special reference to four-engine aircraft." Mr. Wells in 1939, at the age of 28, was appointed assistant chief engineer of the Boeing company.

Meetings

Steel Founders' Society of America—Annual meeting, Feb. 12–13, Chicago, Ill., Edgewater Beach Hotel.

American Institute of Mining & Metallurgical Engineers—Annual meeting, Feb. 14–15, New York, N. Y.

American Society for Testing Materials—Spring meeting and convention, week of March 1, Buffalo, N. Y.

American Society of Mechanical Engineers—Spring meeting, April 26–28, Davenport, Iowa.

Do You Know That—

MICARTA INSERTS placed in the friction base of a clutch body will reduce wear in the clutch body and friction drive ring of automatic screw machines, besides making for smoother and quieter operation. (5)

PARTICLES AS SMALL as 1,000,000th of an inch—1,000th of the diameter of a human hair—can be measured accurately with a new electron microscope developed by General Electric. This is made possible by the use of a new type electron optical system which maintains a "fixed" magnification regardless of voltage variation. (6)

WHAT IS CLAIMED to be the finest filament produced by man or nature is a synthetic textile filament so fine that it is only one-eighth the weight of the finest silk filament. Twenty thousand miles of this filament weights 1 lb. (7)

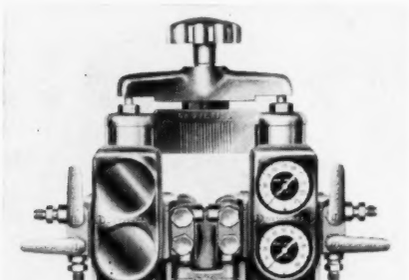
BRASS, copper, bronze, color-treated aluminum and steel and other metals are simulated by a transparent lacquer enamel known as "platelustre," now being used as a substitute for electroplating. (8)

MERCURY that is 99.99995 percent pure is being prepared in a General Electric laboratory at the rate of half a ton daily. (9)

New Materials and Parts

Air Transformer Has Extra Large Capacity

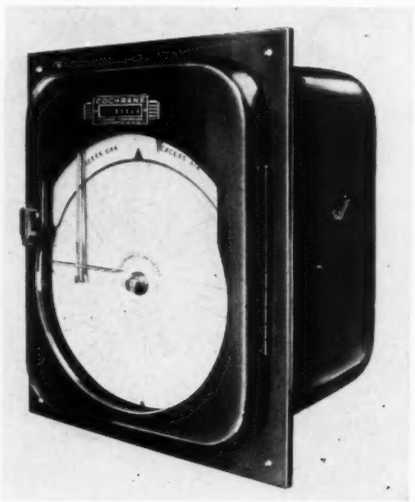
To meet conditions where a large volume of regulated clean air is needed, a heavy-duty air transformer, the double-barreled type HLC, with a capacity in excess of 100 cu.ft. per min., has been developed. The two pressure



regulators are simultaneously controlled by a single knob, although both function independently. The filtering and condensing mechanisms are made of metal and the regulator diaphragms are made of reinforced, oilproof synthetic rubber. Connection to the main air line is made at a single inlet port. DeVilbiss Co., Toledo, Ohio.

Two-Pen Meter Gives Related Records

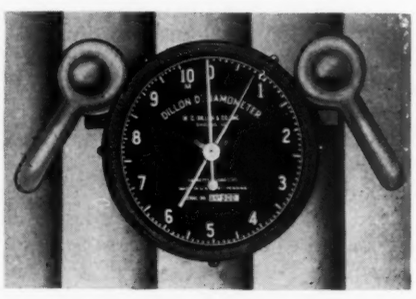
Where panel space is at a premium, or where two related flow records on the same chart are desired for comparison, a two-pen electric flow meter is available. In this arrangement, two flow meter receivers are mounted in one double depth case. For cases where continual reference must be made to the relationship of two records, a ratio indicating pointer can be incorporated. In this arrangement the red target moves to left or right from the center point of the scale. An integrating feature can be furnished on both mechan-



isms, but reading of the rear mechanism integrator requires opening the case and swinging the front mechanism forward. Both receiver mechanisms can be swung out and operated in this position. However, the connection between the rear receiving mechanism and its pen arm necessarily must be detachable, and is arranged with a self-aligning V-notch junction. Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.

Dynamometer Made In Eight Capacities

Ranging in eight capacities from 0-500 lb. to 0-1,500 lb. is the Model AN dynamometer. Features include etched silver numerals on black dials, white main indicator hand, red maximum indicator hand, ¼-in. shatterproof safety glass crystal, rubber gaskets, 8 lb., 4 oz. weight, high duty tool steel construction, galvanized shackle tested



to 25,000 lb., accuracy of ±2 percent, and mechanism that cannot be injured by overload. Size is 8¼ x 6¼ x 3 in. W. C. Dillon & Co., 5410 W. Harrison St., Chicago, Ill.

Self-Locking Nut Fastens Metal and Plywood

Plywood and metal sheets are being fastened together with a self-locking nut which incorporates a wing style, all-metal, self-locking principle. The basket mount of this nut is collapsed with the special clinching tool illustrated. The collapsed mount then clinches the plywood in a grip which withstands, without tearing, the torque applied when a bolt is inserted during production. The nut may be applied in blind applications by a single operator. Booths Aircraft Nut Corp., New Canaan, Conn.

Lubricant Is Colloidal Graphite Suspended in Oil

Colloidal graphite suspended in a specially selected type of lubricating oil goes to make up a lubricant known as Graphicol. Purity tests show as high as 99.8 percent carbon. The claim is that this lubricant effects considerable oil economy, saves power, reduces friction and protects and preserves gliding planes. Pfaltz & Bauer, Inc., 350 Fifth Ave., New York, N. Y.

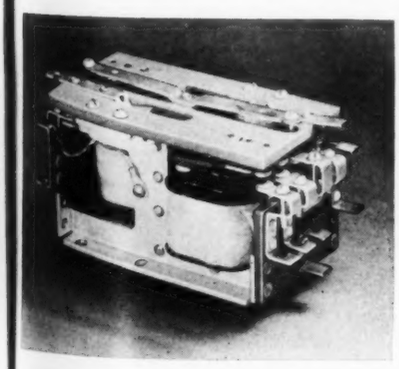
New Models Expand Line of Coolant Pumps

Several new models of coolant and circulating pumps have been added to a line of coolant pumps which have included ¾-in., 1-in. and 1½-in. immersion type units and a 1¼-in. side-

wall mounted unit. The new models added include ¾-in. and 1-in. side-wall mounted types, a 1¼-in. side-wall mounted type for low-submergence applications and a 1¼-in. horizontal type. Illustrated is the side-wall mounted coolant pump. Ingersoll-Rand Co., 11 Broadway, New York, N. Y.

Triple-Purpose Contactor For Aircraft Motors

Starting, reversing and dynamic braking for d.c. split-field, series-wound aircraft motors is provided in a new three-purpose contactor, known as CR-2791-Q100. It is applicable to motors having full load currents up to 10 amp.. and locked rotor current of 60 amp. at 12 or 24 volts, d.c. The functions of several single purpose relays, with their interconnections and mechanical interlocks, are combined in this unit which is compact and light in weight. It has all moving parts statically and dynamically balanced and can be mounted in any position on either a metallic or non-metallic base. Also, it meets 200-hr.. salt spray tests as stipulated by various government agencies. Other features include operation at rated current in ambient temperatures ranging from 95 deg. C. to −40 deg. C. and at altitudes up to 40,000 ft. It will also withstand 95 percent humidity at 75 deg. C. on 48-hr. tests with immediate operation thereafter. In addition, the balanced armature construction assures that when the relay is in either the energized or de-energized state the contact will remain in the open or closed position, even when subjected to mechanical frequencies of 5 to 55 cycles per sec. at $\frac{3}{32}$ in. maxium amplitude ($\frac{1}{16}$ in. total travel) applied in any direction, or when subjected to a linear acceleration of 10G in any direction. General Electric Co., Schenectady, N. Y.

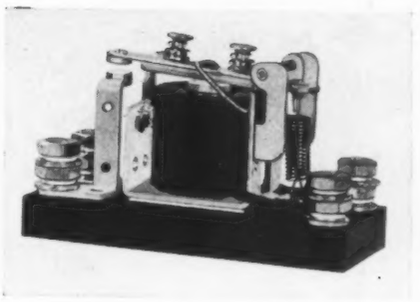


Portable Exhaust Fan Operates in Any Position

Gases and fumes may be eliminated from closed in places with a portable exhaust fan which operates in any position. Known as Octopus Jr., it is powered with a ¾-hp. ball-bearing motor and has newly developed heavy steel wheels. It sucks or blows 2,000 cu. ft. per min. and weighs 70 lb. Adapters for three 4-in. nozzles or four 3-in. nozzles for flexible hose are provided, with caps to close the nozzles not in use. Each 4-in. metal hose of 20-ft. length will exhaust 250 cu. ft. per min., and each 3-in. hose will exhaust over 200 cu. ft. per min. Chelsea Fan & Blower Co., 1206 Grove St., Irvington, N. J.

Relay Meets Air Force Specifications

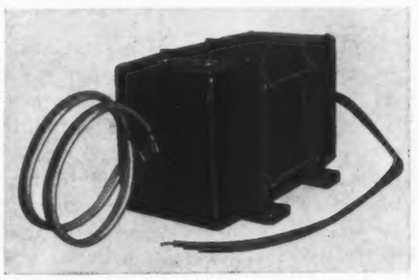
Built to U. S. Army Air Force specifications for remote control of aircraft electrical circuits is the B-2-A relay which has a contact rating of 25 amp.



continuous and 100 amp. surge at 24 volts d.c. It has a single-pole, single-throw normally open contact and weighs 6 oz. Acceleration and vibration resistance are better than 10 G. Metal parts are heavily plated to withstand 200-hr. salt spray test. Guardian Electric Manufacturing Co., Dept. B-2-A, 1629 W. Walnut St., Chicago, Ill.

Test Transformer Isolates Radio Interference

Interference that would affect the testing of radio and communications equipment, the performance of which depends upon accuracy, is eliminated in the Type T-4173 isolating transformer which makes use of a secondary inclosed in a copper shield. Secondary terminal connections are provided by means of a lead-shielded cable, the sheath of which is integrally joined to the copper-inclosing shield. The transformer is normally rated at 2 kva. but is capable of handling an overload of 50 percent. The regulation of the transformer is 1 percent at 1 kva. Acme Electric & Manufacturing Co., Cuba, N. Y.



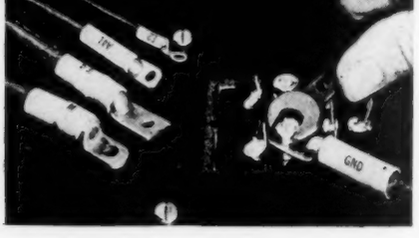
Lightweight Voltage Regulator Is Portable

Suitable for portable generating sets is a voltage regulator that meets radio interference and regulation requirements of the U. S. Army Signal Corps and Radar, and weighs 10 lb. Simplicity of construction, dependability of operation and smooth and close regulation are outstanding features. Dimensions are: height 9 in., width 6½ in. and depth 4½ in. This Type GL-1 voltage regulator is applicable to small a.c.

generating plants having separate exciters. It will control individual generating units operating in parallel with other generating units by using automatic cross-current compensation. The maximum size unit which this regulator will control is limited largely by the field current of the exciter. It is suitable for the control of single, two- or three-phase alternators, and is normally furnished for 50-60 cycle operation. It can be furnished for 110-120 volts, or 208-240 volts. Sensitivity is ±0.25 percent of normal voltage. The unit may be expected to hold the voltage to within 2 percent of normal rated voltage when the generator load is gradually varied from no load to full load and back. Burlington Instrument Co., Burlington, Iowa.

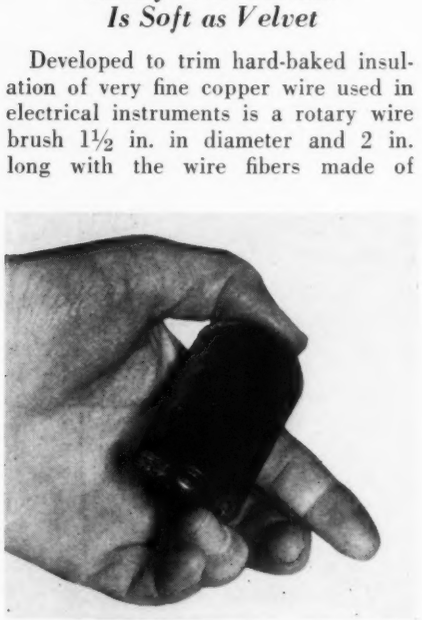
Plastic Tubing Insulates And Identifies Wire

Short lengths of extruded plastic tubing, marked with letters and numerals, serve as insulators of terminal connections and as wire markers. The tubing has high dielectric strength and smooth inside surfaces permit quick application over wires and lugs. Legible numerals are printed on the tubing with ink that resists chemicals, water and oils equal to the resistance of the tubing itself. Colored tubing with either black or yellow symbols, in A.S.T.M. sizes from No. 9 to 3/8 in. inside diameter are available. Irvington Varnish & Insulator Co., 6 Argyle Terrace, Irvington, N. J.



Rotary Wire Brush Is Soft as Velvet

Developed to trim hard-baked insulation of very fine copper wire used in electrical instruments is a rotary wire brush 1½ in. in diameter and 2 in. long with the wire fibers made of



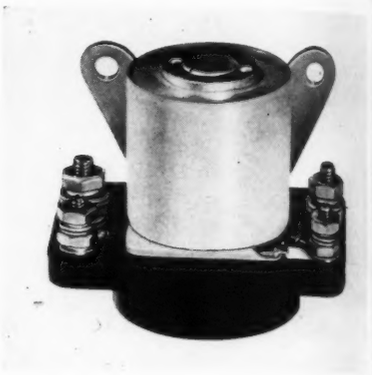
0.0025-in. mild steel wire. The wire in the brush is so fine and so closely packed that there are 242,144 points over the surface area, producing a surface as soft as velvet. Two of these cylinders are mounted in parallel and rotate on spindles at 3,450 r.p.m. or more. The proximity of the brush surfaces is determined by the job to be done. The speed varies with the insulation and size of wire being stripped. The gage of the wire in the brush is determined by the amount of scoring permitted on the work being cleaned. Each brush may be mounted on a motor, or one motor may be used for both brushes. Osborn Manufacturing Co., 5401 Hamilton Ave., Cleveland, Ohio.

Sealing Strips, Gaskets Of "Thiokol" Felt

As an alternate for rubber and synthetic rubber materials, "Thiokol" impregnated felt, a non-critical material, is being produced. The felt is impregnated by a special process and has a weather-resistant surface. It is similar to dense sponge rubber or soft molded rubber, and can be used as a sealing strip or gasket material. It weighs approximately 14 lb. per 1,000 cu. in. and can be supplied in black or dark gray, die-cut pads or strips.—Automotive Rubber Company, Dept. PE-8601 Epworth Blvd., Detroit, Mich.

Solenoid Contactors Approved for Aircraft

Two of five types of solenoid contactor units built to U. S. Army Air Force specifications for remote control of electrically actuated aircraft armaments, instruments and devices are known as B-4 and B-5. The latter of these is illustrated. Both units operate on 24 volts d.c., have double-pole, single-throw, normally open contacts, acceleration and vibration resistance over 10G and metal parts plated to withstand 200-hr. salt spray test. Type B-4 produces a coil current of 300 milliamperes, contacts are rated at 200 amp. and weight of the unit is 31 oz. Type B-5 has a contact rating of 50 amp., produces a coil current of 210 milliamperes and weighs 11.2 oz. Both units are so constructed that they may be disassembled with pliers and screwdriver. Guardian Electric Manufacturing Co., 1629 W. Walnut St., Chicago, Ill.



Fibre Conduit Has Wide Potential Field

Wood cellulose fibers are built up and heat-treated to form rugged tubes with a homogeneous wall structure, constituting a fibre conduit known as "Bermico." The tubes are then impregnated by a special process to produce a chemically inert, lightweight pipe with high mechanical strength and water resistance. Uses include underground installations for electrical cables, replacing of metal conduits, inside drain pipes to carry off rain water, protective jackets to prolong life of metal pipe exposed to liquids or gases, soil pipe and drainage lines and casing in shallow oil wells. Brown Co., 500 Fifth Ave., New York, N. Y.

Oil Level Window Is Pre-Assembled

Preassembly features a new oil window unit for "built-in" installation in an oil reservoir casting. The unit consists essentially of a window of clear plastic assembled in a polished metal housing. A special oilproof synthetic gasket insures tightness between window and frame. The bright background of the housing, together with the plastic window, provides sharp visibility of the oil level and two holes in the metallic

background make for easy passage of the oil. By utilizing a special assembly tool the window unit may be pressed into a reamed hole in the casting, provided the casting wall thickness is ¼ in. or more. A thin coat of oilproof sealing material applied to the surface of the reamed hole just before the window unit is inserted will make certain that the installation is oil tight. The unit is available in sizes to give a window diameter of ⅝, 1, and 1¼ in. Bijur Lubricating Corp., Long Island City, N. Y.

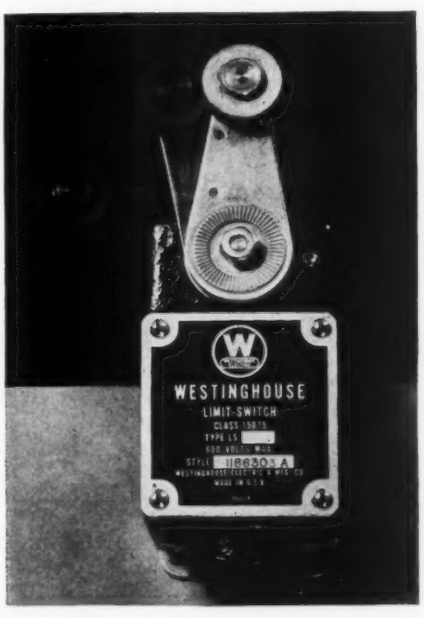
Portable Coolant System Has Centrifugal Pump

Centrifugal type pumps are engineered for continuous service under severe operating conditions and with any cutting fluid. Two models, No. W-88 and

No. W-89, are available. Pump unit has a four-bladed impeller mounted directly on extended motor shaft. Because of the centrifugal pump design, control valves may be closed safely while pump is operating. Intake opening is at top and outlet at the side of casing. Clearance around impeller blade allows dirt and chips to pass harmlessly through coolant system. Larger particles are collected by a large mesh strainer inclosing the lower portion of the pump. Pump motors are completely inclosed. Tanks are made of heavy-gage steel, and are welded. Feed and return equipment is available to adapt the system to a simple single feed installation or to multiple spindle applications. All feed and return tubing is made of extruded plastics. Capacity in gal. per min. of the No. W-89 unit ranges from 7.5 to 3.6 for soluble oil (50 percent solution) and from 2.5 to 0.9 for lard oil (70 deg. F.). Capacity for the No. W-88 unit with the same materials, ranges from 3.75 to 1.9 for the soluble oil solution, and 1.5 to 0.17 for lard oil. Tank capacity of No. W-89 is 5 gal., and that of No. W-88 is 2½ gal. Atlas Press Co., Kalamazoo, Mich.

Limit Switch Has Replaceable Contacts

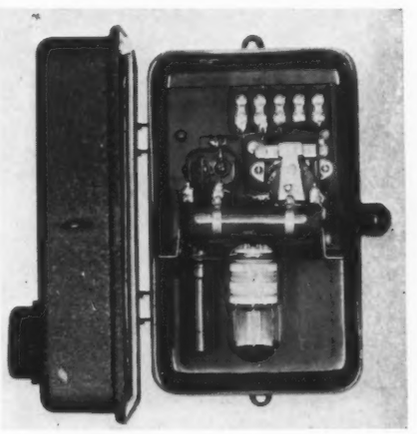
Replaceable double-break, self-aligning, silver-to-silver contacts for long life and dependable operation feature the Type LS limit switch designed primarily for making and breaking control circuits or indicating circuits at a fixed point in the operating cycle. The switch is of the roller arm, spring return type. There is a set of normally open and normally closed contacts. A heavy cast iron inclosure protects the switch from



damage. All wearing surfaces are made of hardened steel or special alloys and all parts subject to corrosion are cadmium plated. The operating arm can be set in any one of 30 positions, and is available in two sizes. The standard arm is 2⅛ in., and the short arm is 1½ in. between centers. Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Photoelectric Control Series Is Approved

Latest developments embodied in the improved series of photoelectric controls, designated as Type A-15, include relay contacts designed to handle heavier direct loads and rated at 10 amp. at 115 volts a.c. The output terminals are those of a single-pole,



double-throw switch for either normally closed or normally open operation. Operating range is 20 ft. with light source L-30 and 40 ft. with light source L-60. Another type is supplied with light source L-30 for 50-ft. operation, and with light source L-60 for 100-ft. operation. Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.

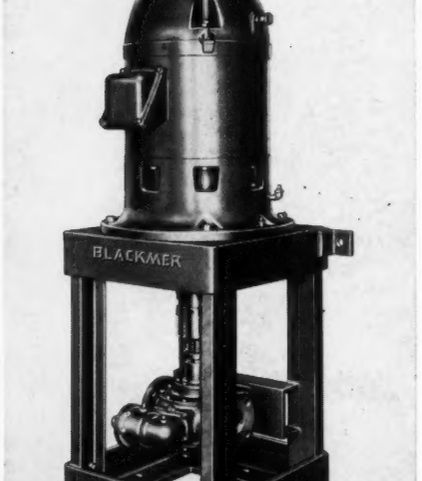
Phenolic Casting Resin For Metal Forming

Announcement of a phenolic casting resin for metal forming dies, jigs, and fixtures, called Durez 7421 liquid resin has been made. It is a thermosetting material which sets by baking at temperatures above 100 deg. C. By using an accelerator, castings can be made at lower temperatures. Standard baking time is two to four hours at 140 deg. F. Normal shrinkage is said to be 0.003 in lacquered wooden molds after a two-hour bake at 140 deg. F. Properties of the casting include compressive strength, 15,000 to 20,000 lb. per sq. in.; impact strength, 0.11 to 0.15 izod;

flexural strength, 7,000 to 9,000 lb. per sq. in.; modulus of elasticity (in bending), 0.5×10^6. Durez Plastics & Chemicals Inc., North Tonawanda, N. Y.

Rotary Pump Is Mounted Vertically

Transfer of oil and other non-abrasive liquids may be handled with a rotary pump which is mounted vertically and driven by a 15-hp. gearhead motor. The pump is built to meet U. S. Navy specifications, and is mainly used for pumping diesel fuel on combat and escort craft. Capacity is 100 gal. per min. at 100 lb. per sq. in. pressure,



handling diesel fuel. The motor is rated at 1,770 r.p.m., reducing to 440 r.p.m. on the drive shaft. The pumping unit is constructed of bronze, and the base is fabricated steel, designed for bottom and back anchorage in mounting. Blackmer Pump Co., Grand Rapids, Mich.

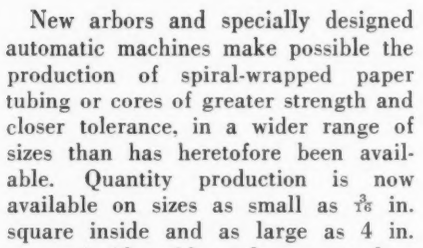
Extended Frequency Range Features Oscillograph

War conditions are responsible for a new cathode ray oscillograph character ized by a greatly extended frequency range, more versatility in the handling of applied signals, and special pick-up means whereby input capacitance is reduced and stray pick-up is eliminated. One of the features of this new unit, known as Type 224, is the Y-axis or vertical deflection response which is uniform from 20 cycles per sec. to 2,000,000 cycles per sec. The X-axis or horizontal deflection amplifier has a uniform characteristic from 10 cycles per sec. to 100 kilocycles per sec. The machine has a comparably faithful square and sinusoidal wave response. Both amplifiers have distortionless input attenuators and gain controls. A wide variety of input connections is available. Also, signals can be applied directly to the deflection plate of the 3-in. tube by means of terminals. All high-voltage

electrolytic condensers are eliminated from the circuit. The unit weighs 49 lb. and measures 14⅛ in. high, 8⅜ in. wide and 15⅛ in. deep. It operates on 115 volts, 60 cycles a.c. Allen B. Du Mont Laboratories, Inc., Passaic, N. J.

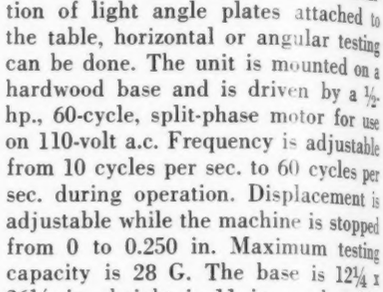
Spiral-Wrapped Paper Tubing in Larger Sizes

New arbors and specially designed automatic machines make possible the production of spiral-wrapped paper tubing or cores of greater strength and closer tolerance, in a wider range of sizes than has heretofore been available. Quantity production is now available on sizes as small as $\frac{3}{16}$ in. square inside and as large as 4 in. square inside, with a tolerance as close as 0.002 in. The paper tubes can be supplied in high dielectric kraft, fish paper, red rope, acetate or combination wound in square, round, or rectangular shapes, and continuous lengths. Paramount Paper Tube Co., 800 Glasgow Ave., Fort Wayne, Ind.



Vibration Machine Tests Articles up to 10 lb.

Simple harmonic vibrations are produced by the Vibratron to test vibration fatigue of parts up to 10 lb. Table movement is vertical, but with the addition of light angle plates attached to the table, horizontal or angular testing can be done. The unit is mounted on a hardwood base and is driven by a ½-hp., 60-cycle, split-phase motor for use on 110-volt a.c. Frequency is adjustable from 10 cycles per sec. to 60 cycles per sec. during operation. Displacement is adjustable while the machine is stopped from 0 to 0.250 in. Maximum testing capacity is 28 G. The base is 12¼ x 26½ in., height is 11 in., and weight is 65 lb. All American Tool & Machine Co., 1014 Fullerton Ave., Chicago, Ill.



Pilot Light Assembly Has Two Parts

For installations where it may be desirable to be able to insert a new lamp at the rear of a switchboard panel without disturbing the electrical wiring, a new pilot light which is assembled in two parts is offered. The lower half snaps apart from the body. Locking pins in the spring member make a secure assembly. The 1-in. jewel is held in a separate ring which slips in the tube, permitting insertion of a new lamp from the front of the panel. Various types of jewels and sockets are available. Gothard Manufacturing Co., 1300 N. 9th St., Springfield, Ill.

Manufacturers' Publications

CELLULOSE PLASTICS—Celanese Celluloid Corp., New York, N. Y. Manual, 64 pages. Properties and applications of plastics made by this company are outlined in non-technical language for the layman, and charts and tables are provided for the technical man. Information is very complete and presentation attractive.

SHAPES—Commercial Shearing & Stamping Co., Youngstown, Ohio. Booklet, 20 pages. Standard steel shapes that can be purchased without die or tool charges are presented in simple, concise and thorough manner particularly handy for engineers.

WEIGHTS AND DATA—Revere Copper & Brass, Inc., 230 Park Ave., New York, N. Y. Handbook, 48 pages. Sixth edition of this handbook includes a new section on technical and mill definitions and illustrations of terms used in the copper and brass industry, in addition to chemical and physical properties, formulas for calculating weights and other significant data of value to anyone who works with copper and brass.

ENGINEERING PROPERTIES OF K MONEL—International Nickel Co., 67 Wall St., New York, N. Y. Bulletin T-9, 16 pages. Complete information on this material is given, including composition, physical constants, properties, working instructions, thermal treatment, corosion resistance, mill products, range of mill sizes and applications.

PLASTICS GUIDE—Monsanto Chemical Co., St. Louis, Mo. Booklet, 16 pages. Basic types of Monsanto plastics, their possibilities and limitations are described in such a manner that busy executives can get a quick picture of what plastics are, what they are doing to help win the war and what they promise for post-war progress.

NE STEELS—Joseph T. Ryerson & Son, Inc., Chicago, Ill. Booklet, 16 pages. Practical, simplified data on the selection and heat-treating of National Emergency steels are given. An explanation of the Jominy end-quench hardenability test is included.

INDUCTION HEATING — Ohio Crankshaft Co., Cleveland, Ohio. Booklet, 16 pages. Tocco operating principles in hardening, brazing, annealing and heating metal are described. Diagrams and photographs of actual applications are included.

RESISTANCE MATERIAL—Keystone Carbon Co., St. Marys, Pa. Folder, 14 pages. Suggested applications and blueprints are covered for a material the electrical resistance of which decreases as temperature increases. Complete basic design data are included.

STEEL DATA—Climax Molybdenum Co., New York, N. Y. Data sheet, 36 pages. This is a revision of Section II of "Molybdenum in Steel", covering chromium-molybdenum steel. Considerable data that were not available when the original section was published are included. Authoritative data from the old section are incorporated so that this revision replaces the old section completely.

RECTIFIERS—Hanson-Van Winkle-Munning Co., Matawan, N. J. Bulleting ER-103, 12 pages. Construction, operation and operating characteristics of copper oxide rectifiers for electroplating, anodizing and electrotyping are described in detail.

MACHINERY STEELS—Crucible Steel Co. of America, New York, N. Y. Folder, 12 pages. Data and stock information are given for MAX-EL 1-B, 2-B, 3, 3½ and 4.

VOLTAGE REGULATOR—Burlington Instrument Co., Burlington, Iowa. Bulletin GL-1, 4 pages. Complete information on the company's Model GL-1 generator voltage regulator is presented.

COOLANT SYSTEM—Atlas Press Co., Kalamazoo, Mich. Catalog C43, 8 pages. Construction, application and operating data on this company's new coolant system are given.

BRONZES—Ampco Metal, Inc., Milwaukee, Wis. Bulletin, 8 pages. Three new bronzes, Grades 15, 17 and 19, are described fully.

MOTOR CONTROL — Westinghouse Electric & Manufacturing Co., E. Pittsburgh, Pa. Booklet B-3123, 16 pages. How Rototrol, a versatile d. c. drive control for use where wide speed range or close regulation is required, increases speed range, keeps motor speed constant regardless of load variations, makes close regulation possible, gives uniform acceleration and deceleration and maintains constant horsepower and uniform tension, is covered.

PLASTICS—R. D. Werner Co., New York, N. Y. Booklet JG-35A, 12 pages. Properties, applications and shapes of tubes, rods and angles are shown.

COOLANT PUMP—Gray-Mills Co., Chicago, Ill. Data Sheet, 2 pages. Describes and gives specifications of Model G-10 portable coolant pump which handles a wide variety of coolants in capacities from 10 to 1,000 gal. per hr.

BUSHINGS—Moccasin Bushing Co., Chattanooga, Tenn. Folder, 4 pages. Composition, properties and specification numbers of self-lubricating bronze bushings are given.

OIL AND GREASE SEALS—Gits Brothers Manufacturing Co., Chicago, Ill. Bulletin, 16 pages. Latest recommendations, applications, diagrams and similar information on this company's line of oil and grease seals is presented.

TRANSFORMERS—General Electric Co., Schenectady, N. Y. Booklet, 20 pages, Dry-type transformers for power and lighting circuits 600 volts and below are described. Complete engineering data are included.

BELLOWS—Cook Electric Co., Chicago, Ill. Booklet, 32 pages. Design, construction, application and selection data are among the information which this publication contains.

METAL PROTECTION—Parker Rust Proof Co., Detroit, Mich. Bulletin, 8 pages. Advantages of treating metal surfaces with the Bonderized Zinc-Flash process are told.

INDUSTRIAL SWITCHES—Square D Co., Detroit, Mich. Bulletin 500, 24 pages. Design data are presented for all types of safety switches made by this company for industrial applications.

COOLANT PUMPS—Ingersoll-Rand Co., New York, N. Y. Bulletin 7074, 20 pages. Complete information, including performance tables, on immersion, side-wall mounted and horizontal type coolant and circulating pumps is given.

RHEOSTATS—Ward Leonard Electric Co., Mt. Vernon, N. Y. Bulletin 60A, 16 pages. Gives full information about field rheostats. Bulletin 69, 4 pages. Describes Ward Leonard 4-in. pressed steel rheostats.

INSTRUMENT PIVOTS—Paraloy Co., Chicago, Ill. Manual, 4 pages. Technical information on the application of Permium pivots for precision instruments is given.

CONTROL—Automatic Temperature Control Co., Philadelphia, Pa. Catalog A4, 4 pages. Application, design and functional data for the Type 2 electric valve operator made by this company are presented.

FANS AND BLOWERS—Hartzell Propeller Fan Co., Piqua, Ohio. Catalog No. 14-A, 40 pages. Complete specification data and information on uses and how to pick the fan or blower for a specific job are shown.

UNIVERSAL GEAR—Piezoelectric Laboratories, New York, N. Y. Bulletin UJ, 4 pages. Contains description and specifications of the Piezo universal gear joint which makes possible the operation of propeller shafts at angles up to 92 deg. with relatively small loss in power.

TUBING AND PIPE PROTECTION—Tubing Seal-Cap., Inc., 215 W. Seventh St., Los Angeles, Calif. Brochure, 12 pages. Various types of caps and plugs for protecting threads on pipe, tubing and fittings are described.

TIMERS—Automatic Temperature Control Co., Philadelphia, Pa. Bulletin, 8 pages. Describes Series 2800 timers for controlling industrial operations on a timed stop-cycle basis. Design features, arrangements and case diagrams are covered thoroughly.

Books and Bulletins

Machine Shop Practice

SHERMAN B. HAGBERG, M. S. CORRINGTON and R. M. BIEHLER—*311 pages, 8x11 in. Blue clothboard covers with wire binding. Published by Harper & Brothers, 49 East 33rd St., New York, N. Y. Price* $2.50.

A good work-project book for vocational training departments and schools which are teaching the fundamental processes and skills involved in machine shop work through the use of various machine and hand tools.

Material presented in the book has been evolved through ten years of use in the machine shop of the Rochester Athenaeum and Mechanics Institute in close cooperation with industry.

Subjects covered include measuring instruments, drill press operations, bench and engine lathes, milling machine practice, shaper, benchwork, tools, punches and dies.

Blueprint Reading for the Metal Trades

W. H. DE VETTE AND D. E. KELLOGG —*132 pages, 8½ x 11 in. Blue clothboard covers. Published by The Bruce Publishing Co., Milwaukee, Wis. Price* $2.50.

Of the many recent books on the subject of blueprint reading, this certainly ranks among the best illustrated, containing many "blueprint" drawings and sketches that make it easy to understand and gain eye practice in the subjects discussed. It teaches blueprint reading by teaching the elements of mechanical drawing and sketching, and covers all standard conventions used in making drawings. Supplementing the text are several pages of tabular dimensional data for screws and gears.

Your Career in Engineering

NORMAN V. CARLISLE—*253 pages, 5¼x8 in., 58 illustrations. Gray clothboard covers. Published by E. P. Dutton & Co., 300 Fourth Ave., New York, N. Y. Price* $2.50.

Young people who are interested in engineering as a career but cannot decide what kind of an engineer to be will find this book helpful because the author goes into considerable detail in describing the major divisions and their specialties. By the same token, an engineer who must advise his own or other youngsters will find much useful information in this book. The bibliographies after each chapter contain excellent suggestions for further reading and study. Appendices list engineering colleges and universities accredited by the Engineers Council for Professional Development and their courses, engineering magazines, names and addresses of major engineering societies and an index.

Materials Testing and Heat-Treating

WILLIAM A. CLARK AND BRAINERD PLEHN—*132 pages, 6½ x 9½ in. Gray clothboard covers. Published by Harper and Brothers, 49 East 33rd St., New York, N. Y. Price* $1.75.

This is a textbook developed as a laboratory testing manual with exercises suggesting many commercial acceptance tests. The tests, however, have been adapted to ordinary school or college laboratory testing equipment. The book is recommended to designers who want a simple explanation and simple examples of methods for testing materials and studying heat-treatment methods.

The section on materials testing gives 35 tests covering every basic type on nearly all classes of materials. The section on heat-treatment gives nine chapters covering all the commonly used methods for heat-treating, with discussions of results obtained.

Industrial Chemistry

EMIL R. RIEGAL—*Fourth Edition. 861 pages, 6x9 in. Green fabricoid board covers. 293 illustrations. Published by Reinhold Publishing Corp., 330 West 42nd St., New York, N. Y. Price* $5.50.

The general scheme of this fourth edition is the same as earlier editions. Two chapters have been rewritten, those on Paper and Pulp, and on Synthetic Textile Fibers. The chapter on Rubber includes the new developments in synthetic rubbers, as well as the latest advances in working natural rubber. The author also covers the innovations in the technology of petroleum such as aviation gasoline, alkylation and the Houdry catalytic process. Some emphasis has been placed on the manufacture of aluminum metal, and of magnesium metal. Under radium, radiography is briefly described for the first time.

Engineers will appreciate the broad scope of the book and the author's method of showing the significance of chemistry in industrial processes.

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A Career in Engineering

LOWELL O. STEWART—*48 pages, 6x9 in., 24 illustrations. Paper covers. Occupational Monograph No. 30 of the American Job Series. Published by Science Research Associates, 1700 S. Prairie Ave., Chicago, Ill. Single copies, 60 cents, rates for quantities.*

All phases of engineering are described briefly and concisely in this monograph. The manner of presentation—a civil engineer in charge of construction of a big dam telling local farmer boy about engineering work—combined with the brevity and conversational style should make this publication popular with any young person who wants the "lowdown" on engineering in as short a time as possible.

Eyes for Industry

24 pages, 6x9 in. Paper covers. Published by General Radio Co., Cambridge, Mass.

Stroboscopic techniques, the sub-title of this pamphlet, is a very descriptive term for it. Types of stroboscopes, qualitative measurements, quantitative measurements, typical uses, operating hints and techniques, photography and specifications are covered thoroughly. The material is presented in an interesting manner, profuse illustrations being partly responsible.

Tin-Base Bearing Metals

W. T. PELL-WALPOLE, J. C. PRYTHERCH and BRUCE CHALMERS—*Tin Research Institute Publication No. 111, reprinted from the Journal of the Institute of Metals, Vol. 68, 1942. 40 pages, 5½x8½ in. Published by the Tin Research Institute, Fraser Road, Greenford, Middlesex, England.*

Factors governing the adhesion of tin-base bearing alloys to various backing metals are reported. The conditions for obtaining sufficient bonds are considered, and the many factors affecting the conditions in manufacturing operations are examined. A large number of tests, which indicate the most suitable methods of preparing and tinning the bearing shell, and of casting and cooling the lining, are described. The results of thousands of individual tests show the effects of variations in alloy composition, mold design, temperature of metal and mold and rate and direction of cooling, in relation to both hand pouring and die-casting and also to centrifugal methods of production. The part played by shrinkage cavity at or near the bond is also examined and methods of operation are suggested by which this trouble may be avoided.

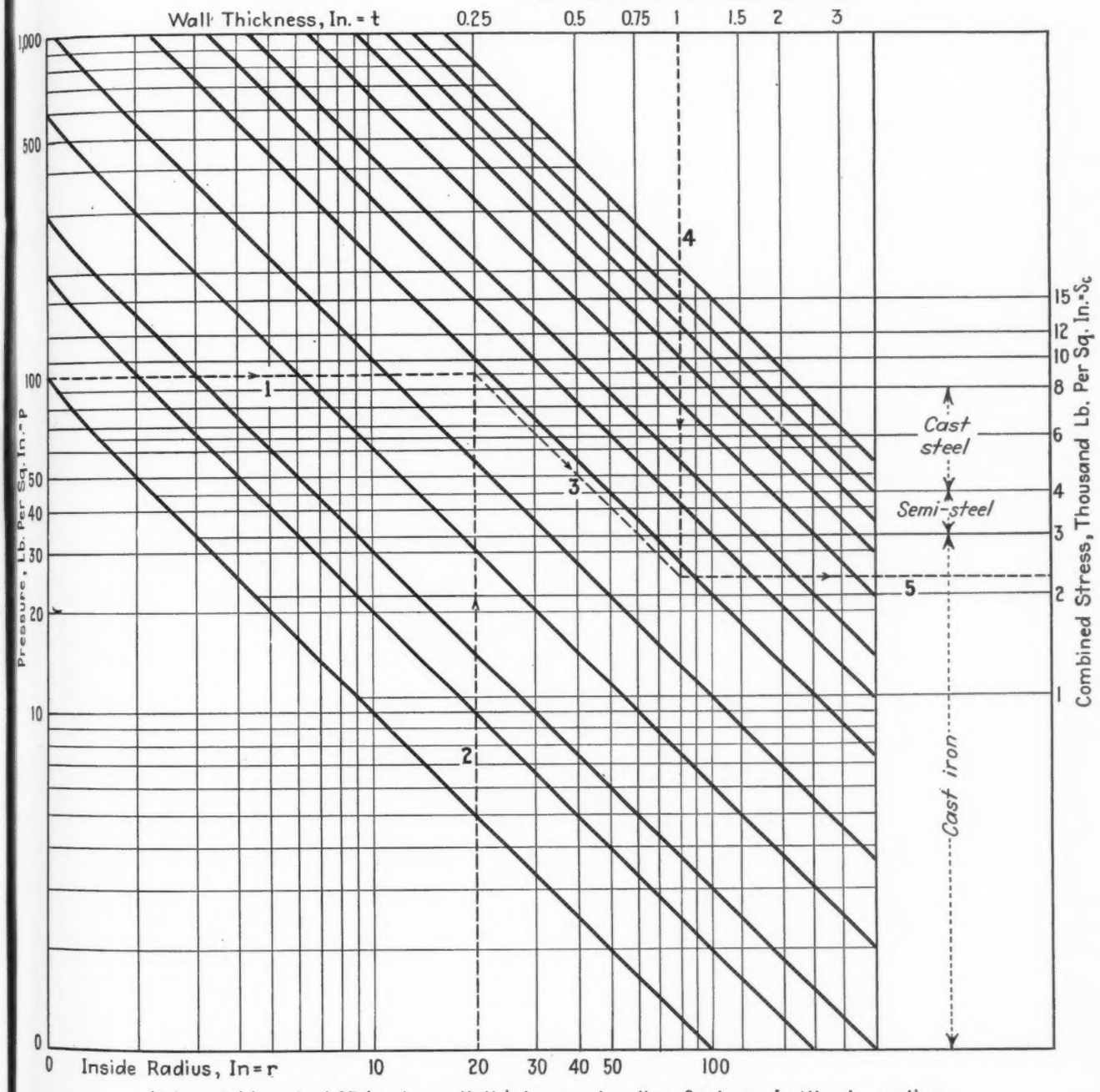
Stress in Straight Pipes Under Internal Pressure

H. W. HAMM

Hoop stress $S_H = \frac{p \cdot r}{t}$

Longitudinal stress $S_L = \frac{p \cdot r}{2 \cdot t}$

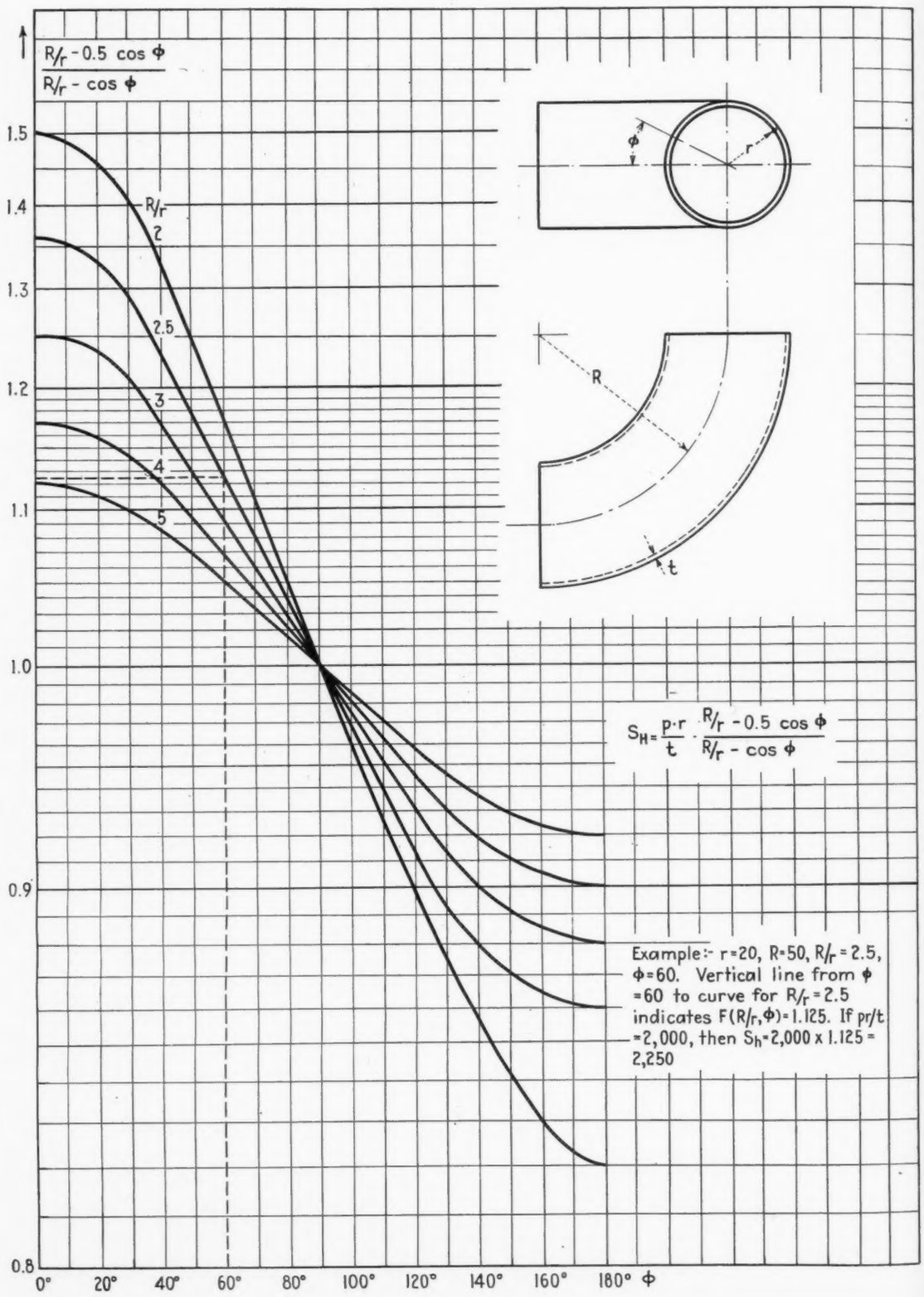
Combined stress $S_c = \sqrt{S_H^2 + S_L^2} = 1.12 \frac{p \cdot r}{t}$



Note: Add up to 0.25 in. to wall thickness to allow for irregularities in casting
Example: p = 100, r = 20, t = 1. s = 2,240. Intersection of lines 1 and 2 represents product pr and intersection of lines 3 and 4 represents S_c, which is indicated by line 5 to the S_c scale

Hoop Stress in Pipe Bends Under Internal Pressure

H. W. HAMM



PRODUCT ENGINEERING ✦ REFERENCE BOOK SHEET